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ENHANCING STATISTICS EDUCATION WITH JAVA APPLETS

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DECLARATION

I, Edmund Yung, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Education, in the School of Education, University of Leicester, is wholly my own work and unless otherwise referenced or acknowledged. This document has not been submitted in any form for another degree or diploma at any university or other institute of tertiary education.

Ed Y.

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October 15, 2008

ABSTRACT

Statistics has always been considered to be one of the most difficult sciences. However, with the rapidly changing world towards more and more technical areas and becoming more global, ever increasing in-depth knowledge of statistics is demanded since massive data of more and more complexity and size are a lot easier to gather and thus the need to be understood and analyzed. Although this changing demand is present and very much visible, our methods of teaching statistics unfortunately have not been changed dramatically; most educators are still relying on chalk-and-talk teaching methods.

Advances in global technology have opened up and indeed created the possibility of new ways of teaching and learning statistics. Computer and the Internet, in particular the World Wide Web (WWW), have combined to become a very good tool that can be used for basic statistics education. Armed with the latest WWW technology, educators can now create an interactive learning environment for students to learn statistics by using Java applets.

The purpose of this study was to investigate the effects of Java applet-based instruction in comparison with traditional instruction on college students' achievements, attitude and satisfaction in an introductory statistics course. This study was conducted at the Macau Polytechnic using a quasi-experimental, pre-test/post-test non-equivalent control group design. The experimental group involved 37 undergraduate students who received Java applet-based instruction; the control group involved 38 students who received traditional instruction.

Results showed that (a) the Java applet-based instruction group had significantly better achievement than did the traditional group; (b) students reported a more positive attitude toward the subject matter after attending the applet-based class; furthermore (c) a significantly higher level of satisfaction was found in the Java applet-instruction group. It was concluded that a Java applet-based instruction format should be considered as a substitute to the traditional instruction format.

KEYWORDS

Internet, World Wide Web, Statistics Education, Java, Applets, Teaching.

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CHAPTER 1

INTRODUCTION

This thesis investigates the effects of Java applet-based instruction in comparison with traditional instruction on college students' achievements, attitude and satisfaction in an introductory statistics course in an institution of higher education. Section 1.1 includes the context for the research. Section 1.2 examines the learning theories which are relevant for this investigation. Section 1.3 will discuss the influences of technology on higher education. Section 1.4 addresses the issues of educational software. Section 1.5 will look at the educational impact of the World Wide Web. Section 1.6 examines the concept of interactivity. Section 1.7 will discuss collaborative learning. Section 1.8 provides a list of technical terms and special names used throughout the thesis. Section 1.9 discusses the objectives of the research study. Section 1.10 addresses the research questions. Section 1.11 will present the background of the research. In Section 1.12, an explanation of the originality of this research study will be given. Section 1.13 will explain the rationale for choosing statistics. Section 1.14 looks at the significance of this study. Section 1.15 provides the outline of this thesis.

1.1 CONTEXT OF THE STUDY

Statistics is the science of systematically gathering, analyzing and interpreting data for the purpose of drawing and presenting conclusions and based on these conclusions, new and conclusive decisions can be made.

From earlier times when statistics was used in more scientific studies, it has evolved into applications in nearly all our everyday activities. From the most recent unemployment figures, visualized stock market developments, analysis of sports results or HIV infection rate forecasts, society has indeed accepted statistics as part of its daily life and thus encouraged the introduction of this science to its population at a younger age.

Due to the pervasive nature and growing importance of statistics globally, statistics has correspondingly become part of many curricula, both at the graduate and postgraduate levels. The growth of statistics is directly attributable to its use in the validation of research hypotheses and the quantification of research findings in all academic disciplines including those from the pure sciences such as biology and botany, social and health sciences including sociology and psychology, and engineering and business (Giesbrecht, 1996). Specifically in the areas of engineering and business, statistical analysis has become a widely used tool for quantifying the dynamics of these academic disciplines in addition to clearly and succinctly defining the interactions of social sciences with these two highly quantitative disciplines.

However, there are certain fundamental and basic statistical concepts that are commonly considered difficult for students to comprehend at an intuitive level. These concepts require students to grasp a variety of skills, including the handling and compilation of quantitative/qualitative data, graphical insights as well as an understanding of mathematical theory. Statistical analysis has become so pervasive in the pure sciences, social sciences, and physical sciences in relation to the growth of data sets brought on by increasingly more robust software applications. This increasing depth and complexity of data sets is in turn bringing an entirely new level of requirements on students in these academic disciplines. The result is that students now more than ever, who wish to excel in their chosen fields of study, must know statistical concepts and techniques if they are to complete not only their academic work, but also excel in their chosen professions.

Ironically however the teaching techniques have not kept up with the changing demands both in individual academic disciplines and within the academic teaching community itself. Traditional approaches to teaching statistics including relying purely on a whiteboard, overhead projector, or the use of hand gestures and simply lecturing on statistical formulae is not congruent with the demands being place on students today to quickly interpret, analyze, present and apply results. Visualization of even basic statistical concepts can be difficult for students. Morris and Szuscikiwicz (n.d.) claim that despite the importance of statistics, many students encounter difficulty in their introductory statistics courses. To help students with these difficulties, an attractive and potentially dynamic new way to update current teaching methodology has been developed by using tools based on the Internet. These developments are part of fundamental changes in the way in which teachers teach and students learn. The educational arena is undergoing a paradigm shift (Barr and Tagg, 1995) from teacher-centred learning (objectivism) to student-centred learning (constructivism). "The Internet and in particular the World Wide Web (WWW) promise to be some of the most powerful classroom tools available" (NVATA, 1995). Java is a thin-client based programming language that is ideal for capitalizing on the intersection of the World Wide Web (WWW) and the unmet needs of students. Java is suitable for the preparation of visual and interactive simulations on the WWW (Blejec, 2003). The intention of the research was to use Java as the basis for creating an interactive suite of applets that were specifically designed to enhance and clarify key statistical concepts, aimed at the students' needs in introductory statistics classes.

Sun Microsystems pioneered the development of the Java programming language, launching it in 1995. Designed by software engineers after the C++ programming standard, Java is specifically designed to be used across a wide variety of operating systems and platforms. In fact the developers felt it would be best if Java was portable across as many operating systems as possible, relying only on a browser to function. Java is a unique programming environment in that it is self-contained within Internet browsers. Programmers developing applications in Java are able to produce and play videos and images online (still or animated), play audio files, and receive user input from the mouse and keyboard through what is called the Java Virtual Machine logic. There are literally thousands of Java-enabled browsers in existence, with the two most well-known being Netscape Navigator 2.0 or higher or Internet Explorer 3.0 or higher.

Sun Microsystems continues to be instrumental in the definition of Java programming standards. The company's definition of Java 2 Platform, Enterprise Edition (J2EE) is revolutionizing the development of Internet-based applications for distance learning and computer-based instruction, in addition to the development of Internet-based applications of all types.

1.2 LEARNING THEORIES

Within educational circles, the two most popular theories of learning are: objectivism (also known as instructivism or behaviourism) and constructivism (also known as interpretivism). A.D. Carswell (2001) states that "Objectivism argues that there is an objective reality, and that the goal of learning is to understand this reality and change behaviour accordingly" (p.2). In addition, Dupin-Bryant (2004) defines the objectivist approach as "a style of instruction that is formal, controlled, and autocratic in which the instructor directs how, what, and when students learn" (p.42). The objectivist model is teacher-centred. According to the objectivist theory, the role of the teacher is to disseminate knowledge to the students. The teacher is in control of the material and the pace of learning. The students are passive recipients of knowledge and they are not actively involved in the process of learning.

The polar opposite of objectivism is constructivism. Constructivism was derived mainly from the work of a number of constructivists (Piaget, 1970; Bruner, 1962 and 1979; Vygotsky, 1962 and 1978; Papert, 1980 and 1983). Jean Piaget, the father of constructivism, provided the solid foundation for modern day constructivism. Bruner believed that learning is an active process in which learners construct knowledge based upon their experiences. Focussing on the cognitive development, Vygotsky contended that students could complete tasks at higher intellectual levels if they are asked to work in a collaborative environment, rather than individually. Papert's constructionism emphasized the use of technology in constructivism. Papert asserted that technology could provide new ways of learning and for enhancing creativity. He also emphasised in a speech that "the new technologies are very, very rich in providing new things for children to do so that they can learn mathematics as part of something real" (Papert, 1980, p.1).

In contrast to objectivism, constructivism is based on the concept that "the only important reality is in the learner's mind, and the goal of learning is to construct in the learner's mind its own, unique conception of events" (Carswell, 2001, p.2). In contrast to objectivist theory, within the constructivist model the students are active learners, rather than passive recipient of knowledge. Carswell (2001) goes on to say that "the learners actively participate in their learning process by discovery, with the instructor as the mediator of the process" (p.3). The constructivist model promotes a learning environment which supports "multiple perspectives or interpretations of reality, knowledge construction, context-rich, experienced-based activities" (Jonassen, 1991, p.28). Additionally, the constructivist approach is considered as "a style of instruction that is responsive, collaborative, problem-centred, and democratic in which both students and the instructor decide how, what, and when learning occurs" (Dupin-Bryant, 2004, p.42). The constructivist model is student-centred. According to constructivist theory, the students exercise more control over the pace of learning. The students are the active constructors of knowledge. The teacher only acts as a facilitator of the process of learning. Students learn better when they are actively involved in their own learning process. The constructivist learning environment encourages higher-order thinking and problem solving.

While the process of teaching did not change in substantive ways up until the end of the 20th century, some profound changes have taken place in the last decade or so that are providing students and educators alike with much to consider today (Robertson, 2003). The driving force behind this paradigm shift has been a combination of changes in learner expectations as well as new views concerning what teaching techniques work best in a modern classroom. In the past, the predominant paradigm that has traditionally been used for delivering higher educational services has been the objectivist-based instruction/teaching schema (Green, 1999). In this regard, Carwile (2007) reports that, "Within an objectivist schema, the instructor identifies the course objectives required of students and then systematically arranges the content to reach those goals. The instructor teaches the students a defined body of knowledge within teacher-prescribed boundaries" (p.68). According to Paniagua-Ramirez, Barone and Torres (2004), in the traditional objectivism-based instruction/teaching paradigm, "Faculty transfers information in a manner that allows the acquisition of that information by the student" (p.1). The paradigm shift that is taking place, though, involves a fundamental shift to a constructivist approach to learning (Barr and Tagg, 1995). According to Zahorik (1995), constructivists believed that knowledge is actively created or constructed by the student, not transmitted by the teachers.

Because humans are by nature social animals, this emerging paradigm appears to provide a superior approach to helping people learn based on its emphasis on feedback from others and the active "manipulation and testing of ideas in reality." Some academic commentators argue that the paradigm shift in education has taken place to the extent that many learners have come to expect these new approaches to teaching rather than being simply a passive recipient of lectures or traditional training sessions. For instance, according to Khan (2005), "New developments in learning science and technology provide opportunities to create well-designed meaningful learning environments for diverse learners. With the increasing use of a variety of approaches in learning in the information age, learners are moving away from wanting to be taught mostly in lectures or direct training sessions. There is no doubt that they now expect more variety in the ways that they can learn, and flexible learning helps provide this variety" (p.137). These are highly appealing qualities for many learners who bring a great deal of life experience and computer skills to the classroom and who may excel in environments where these qualities and expertise are shared with others. As Carwile (2007) emphasizes, "The constructivist model promotes a learning environment that has richness – both depth and breadth. Specifically, constructivists believe in independent exploration by students that will lead to a deeper understanding of the content" (p.69). For constructivist learning to take place, students must relate new learning to their prior knowledge. According to "Learning Theory: Constructivist Approach" (2008), "Constructivists believe that prior knowledge impacts on the learning process. In trying to solve novel problems, perceptual or conceptual similarities between existing knowledge and a new problem can remind people of what they already know" (p.2). Although this approach to the delivery of educational services is not necessarily new, the paradigm shift taking place in education today reflects a dramatically different view from the past concerning what specific roles teachers should play in the evolving classroom and what actions and behaviors are required on the part of students to complete the learning cycle.

From a strictly pragmatic perspective, this paradigm shift is important – and valuable -- because it just makes good business sense to use the most effective methods available to help achieve positive academic outcomes. More importantly, perhaps, this paradigm shift has also assumed new importance because of the enormous potential it affords to educators and learners alike in achieving these goals. By any measure, though, the introduction of computer-assisted and interactive learning techniques has fundamentally altered the traditional approach to teaching. Indeed, this paradigm shift in the delivery of educational services has clearly been facilitated, or perhaps even made possible and even inexorable, through the introduction of increasingly sophisticated and powerful technologies that have created new opportunities and challenges for educators and students alike, and these issues are discussed further below.

1.3 TECHNOLOGY AND ITS INFLUENCE ON EDUCATION

Technology is increasing its impact on higher education by making information and learning experiences more immediate, focused, and customizable to the individual needs of the student. The growth of learning tools and processes that rely on the agility and speed of publishing attributes of the World Wide Web show significant potential for increasing the effectiveness of learning strategies into the future as well.

Despite the very positive perceptions of what learning strategies could be created and customized to the students' unmet needs specifically in statistics courses, the typical classroom is lacking in progress. The typical classroom of today has been, in the best of cases, integrated with computer systems on a network that allow for file and data sharing in class from the instructor. Yet the use of software and specifically applications delivered over the World Wide Web in tailoring learning strategies for students in more complex subjects is still embryonic in its growth. There is a dearth of materials today for assisting students in learning the fundamentals of more complex subjects. Instead the majority of classes are primarily lecture-based with chalk, a blackboard and possibly an overhead projector.

The use of Microsoft PowerPoint and computer-compatible overhead projectors has replaced the chalk and blackboard, yet this has just hastened the publishing of more materials as opposed to increasing student participation in the learning process. During the last forty years, starting in 1960 and progressing through the 70s, there was increasing emphasis on television-based instruction. However, the advent of personal computers and applications quickly replaced this teaching strategy. What has become apparent is that the use of technology for its own sake as an enabler of teaching strategies and techniques does not work; rather it is the selective application of technologies to students' unmet needs that matters most. This necessitates a lifetime learning commitment however, which is becoming possible with electronic education initiatives on the World Wide Web. Given the impact of the Internet on our daily lives, many theorists predict that the lines between formal and informal education will increasingly blur. Dierker (1995) states that the duration of learning and location of learning will also change, with the classroom increasingly becoming the home, and the commitment to learning, due to electronic education, being much longer in duration.

It was not so long ago that the presence of a computer in a classroom was a curious anomaly rather than an accepted and even expected part of the learning environment, but that has all changed today. Around the world, computers and Internet access have provided students and teachers alike at every grade level with new opportunities to use technology in meaningful ways and new techniques continue to be identified even as the technology itself continues to improve and evolve. Young adults entering college today can reasonably be expected to possess a wide range of computer skills that they will want to bring to bear on their learning process, so it is important for educators to understand what these learners want from their educational experience and to develop curricular offerings that satisfy these changing expectations in ways that are timely and responsive. The significant benefits that can be realized in this fashion, though, tend to accrue to educational settings that take into account the unique needs of the students involved, and how technology can contribute rather than interfere with learning.

In their study, "Transforming Learning with Technology: Lessons from the Field," Rice, Wilson and Bagley (2001) point out that, "Professional organizations in many subject areas have emphasized changing the way subject matter is taught by actively involving students in critical thinking, problem-solving, decision-making, and exploration. One way to accomplish this is with the use of technology and constructivism, although many barriers to technology integration exist" (p.211). According to these authors, one of the most challenging obstacles to the comprehensive integration of constructivist teaching approaches is to overcome the longstanding notion still held by many administrators concerning the need for the traditional classroom, where ". . . students sit quietly while a teacher stands at the front of the classroom and lectures to them. Many of these individuals do not use technology and do not understand the principles of contructivism, so teachers who use technology and constructivist methods are penalized" (Rice et al., 2001, p.212).

Pioneers in the vanguard of educational reform have historically encountered this type of reluctance to embrace substantive change in the status quo because such initiatives represent change and change is frightening for many people – even educators. Consequently, the reluctance on the part of some administrators to recognize and facilitate the transition to a constructivist approach is perhaps not surprising, but it does represent a fundamental constraint to the introduction of these methods in today's classrooms. In this regard, Rice and her colleagues advise, "This is a barrier many teachers will continue to encounter until administrators can be convinced of the benefits of both technology and constructivism. It is difficult for teachers struggling to integrate technology to also fight against administrators who do not use technology and do not give the teachers the support needed to change teaching techniques" (p.212). In the final analysis, these authors suggest that, "The ideal situation would be to have technology integrated throughout teacher education programmes to provide skills and knowledge as well as serving as a model of how the technology and constructivism can be integrated throughout the curriculum" (Rice et al., 2001, p.212). The use of technology, though, represents a perfect addition to the paradigm shift taking place in the classroom today. For example, in their study, "Constructing on Constructivism: The Role of Technology," Nanjappa and Grant (2003) emphasize that, "A complementary relationship exists between technology and constructivism, the implementation of each one benefiting the other. . . . Thus, the task of the learner is seen as dynamic, and the computer makes available new learning opportunities" (p.4). This mutually beneficial relationship is one of the key advantages of the use of technology in the emerging constructivist approach to education. According to Malabar and Pountney (2002), "The use of technology allows the opportunity to change the nature of the material to be taught and learnt from routine-based to discovery-based activities. Knowledge is built up from personal experiences, and making these experiences more dynamic will assist in the development of cognitive structures" (p.3). This does not mean, though, that students can simply push a few buttons and sit back and assume that something meaningful has been learned. As Gonzalez-Major (2005) emphasizes, "Technology cannot teach students. Rather, learners should use the technologies to teach themselves and others. Meaningful learning will result when technologies engage learners in: knowledge construction, not reproduction; conversation, not reception; articulation, not repetition; collaboration, not competition; and reflection, not prescription" (p.2). While every educational setting will be unique, it is reasonable to assume that many of these issues will confront educators as they seek to integrate technology into their teaching methods in a meaningful way.

1.4 EDUCATIONAL SOFTWARE

In addition to re-ordering the classroom, technology is also significantly changing another major aspect of education, and that is the textbook. The need for accreditation standards underscores the role of textbooks for the foreseeable future, yet with the growth of computer-based instruction and the growing sophistication of software development tools, the development of courseware that supplants and more fully defines the key concepts of textbooks is imminent. In conjunction with the technological developments that favour the use of more on-line or digital textbooks, there is the customization aspect of textbook development and OnDemand production. For many instructors the ability to tailor a digital textbook to the specific objectives they have for their classes can greatly increase learning effectiveness. The combination of inexpensive graphics video terminals and the plummeting prices of personal computers have led to the development of high performance multimedia laptop and desktop systems that integrate animation complete with audio and video as part of the learning experience.

While educational software has been available for several decades, the reliance on and use of printed materials has not diminished. In fact educational software has become more complimentary in its support of printed materials. The use of educational software to supplement textbooks is also now commonplace, as many publishers are offering complimentary websites that have both additional content and links to websites of interest for students in the courses taught. Glennan and Melmed (1996), in describing their vision of a national strategy for educational technology, see the dual challenges of first training teachers to use technology effectively, and second, defining strategies and plans for assuring a plentiful supply of educational software that continually increases in quality and effectiveness. These researchers contend that there is a dearth of educational software available, specifically at the more advanced educational levels and subjects. This emphasises the need for a more effective approach to assuring effective software is produced for the advanced educational levels.

As the price of personal computers and laptops continue to drop, all of which can reproduce and run educational software that includes digitized audio and video, the challenge of how to create these software applications at an affordable cost remains a challenge. In fact researchers like Soloway (1998) have shown that it is often difficult to make a profit developing educational software. The reasons for this are many and include the limited visibility that developers have into the market needs of higher education institutions, high production costs with high risk of sales, and competing projects that have much more established and lucrative opportunities. Many of the smaller software developers who have the expertise in-house, instead of working to expand the market for educational software, would rather focus on more lucrative software segments that will net higher sales without having to play the role of market evangelist. Clearly, there is the need for larger software companies including Microsoft Corporation to play the role of market-maker in the higher education software segment.

1.5 THE IMPACT OF THE WORLD WIDE WEB

From a basic communications protocol to the world's most powerful communications platform, the World Wide Web (WWW) has progressed from hosting rudimentary test, graphics and sound files to become a major publishing medium that today hosts full motion video, training materials, and a host of multimedia applications, governed only by the bandwidth of the user. Today, it is common-place to find distance learning programmes and on-line programmes that are little more than a syllabus and an URL for gaining access to a teaching portal. The fact that many students in graduate-level programmes are also required to travel globally has also hastened this development.

Defined by Khan (1977a), as an innovative approach to delivering courses over the World Wide Web, Web-based Instruction (WBI) is considered by many to be the most rapidly growing instructional technology (Crossman, 1997); yet there is a dearth of evidence that has yet to quantify this new medium's effectiveness (Reeves and Reeves, 1997). What does emerge however from a study of this area is that WBI is not simply an in-class electronic substitute for lectures despite its low cost. According to Bostock (1997), merely automating an existing lecture-based approach to teaching is ineffective. The need for consistently high levels of instructional design standards and the development of both educational applications and Web sites which have interactive media that reflect those standards is critical, according to Gillani and Relan (1997) as many today do not.

Given the advent of the World Wide Web (WWW) the ability of instructors to quickly create courses has risen dramatically. A case in point is the Microsoft Word processing application that today allows users to save documents out in any variety of Web-compatible formats. The consequence is that any instructor has the ability to deliver all the essential materials for a course quickly. This includes the assignment, definitions, syllabus, lecture and laboratory notes, and many other materials. Microsoft's continual focus on exporting documents compatible with the Internet is setting the foundation for Web-based teaching strategies as well.

The development of multimedia programming techniques and advances in design standards for instructional Web sites is increasingly including the need for active learning strategies, techniques and programmes to deliver greater value to the students. According to Brooks (1997), of all the design criteria, the integration and support of active (constructivist) learning is by far the most challenging aspect of creating interactive learning environments. With the greater need for interactive and highly customized learning experiences, developers have increasingly had to rely on JavaScript, Visual Basic (VB), and increasingly AJAX as approaches to enriching the learning experience whilst also creating web pages that load quickly enough to be of use in non-broadband environments. AJAX, JavaScript, and Visual Basic are all programming and scripting languages that can be interpreted by any web browser. Each of these languages are specifically created to give the user of applications delivered via a browser, an opportunity to interact with them more efficiently than would be the case in other forms of presentation. A good example is the application Google Earth, written in Java that allows users to scan across entire regions of continents and then drill down to the specific address. The overlaying of these high performance web browser applications with graphical data that has intelligence associated with them has increasingly become the areas of focus for web developers.

Java-based graphics differ from the scripting languages that run purely within a browser window. Java however runs as an applet and includes the code within the applet container, and executes within the browser. Java relies on a Java Virtual Machine (JVM) within the browser to compile the Java code on the fly, and uses widgets to create the user interface, where audio-based applications are predominantly delivered through this approach. Companies including Macromedia and their Shockwave application capitalize on the advantages Java presents and focus on the delivery of high quality multimedia applications on-line. Asymetrix Toolbook is another vendor in this area that focuses on using Java to further gain greater performance advantages for multimedia applications.

Creating multimedia-based websites that include highly interactive features, applications and functionality are inordinately more time-consuming and requiring of more specialized skill sets compared with creating websites with simple text and graphics. It is certainly true that the greater the degree of complexity and interactivity in multimedia sites, the greater the level of programming expertise, and as a result, the higher the cost to produce them. Contributing to these levels of complexity are the more advanced applications and techniques required to create effective multimedia-based websites which are aimed at simplifying complex concepts for students' learning. It is certainly possible to create these websites that have high levels of multimedia-based content, advanced navigational features, and innovative personalization features for example, yet more research is needed to see if this specific type of Web-based teaching is most effective in a complimentary role to traditional instruction, or is a potential suitable replacement.

Kerr et al. (2004) have commented there is the need to compare new technologies, methods, or theories with the current standard. To evaluate the effectiveness of the Java applets, 35 students enrolled in an introductory statistics course either attended the Java applet-based section or the traditional class. A quasi-experimental non-equivalent control-group design was used. Therefore, the purpose of this study was to determine if there were differences in student performance, attitude, and satisfaction for students instructed via applet-based instruction compared with those instructed via traditional instruction.

1.6 INTERACTIVITY

One of the fundamental concepts of student-centred learning is the need to incorporate an interactive element into the educational model. According to Bigus (2004), "Interaction or interactivity refers to how different components in a learning environment can act and react with one another to facilitate learning. This becomes especially important in distance learning environments and web-based courseware where the learners, instructors, and content are often separated from one another in terms of both distance and time" (p.1). In the paradigm shift taking place today, this means using learning approaches that actively involve students in the learning process rather than having them remain submissive and unresponsive observers. For instance, Malabar and Pountney (2002) emphasize that, "Computer-based environments with visually compelling displays, together with facilities for interaction, can provide the setting for more dynamic, powerful experiences. These environments are filled with stimuli which encourage rich constructions by students" (p.3).

Because resources are by definition scarce, it is vitally important that educators incorporate learning methods that have been shown to provide superior results. To this end, interactive approaches to educational services delivery appear to provide a significant return on the investment of resources for this purpose. For example, according to Dade (2005), "Our research shows that the integration of interactive media into learning experiences profoundly shapes students' educational experiences" (p.1). Likewise, others report that, "Interactivity is considered an important benefit of Web-based instruction and is believed to influence student retention in distance education and to enhance student learning"; however, the downside to this approach is an increased sense of isolation on the part of many students (Interactivity Literature Review, p.1).

Because the technology is available and is becoming increasingly more powerful and less expensive in line with Moore's Law, it therefore just makes good business sense to take advantage of these innovations in as many ways as possible that contribute to improved academic outcomes (Robertson, 2004). Moore's Law, named for Gordon Moore, one of the founders of Intel, maintains that computer processing speeds will continue to double every 2 years or so, and this maxim has held true since it was first propounded in 1965 (Moore's Law, 2008). The technology exists to provide students at all levels with meaningful interactive learning opportunities and students have come to expect this type of learning opportunity as well. Moreover, many of these interactive learning opportunities are free or virtually free and the various ways in which such learning techniques can be applied is limited only by the educators' imagination, wherewithal and access to the resources needed to implement and sustain such initiatives. However, there are some important factors that must be considered in developing such interactive approaches.

For example, there are different types of interaction involved in virtual learning environments compared to traditional classroom settings. According to Moore (1989), there are three types of interaction involved in the process of learning: (a) learner-content interaction which refers to the interaction between the student and the course material; (b) learner-instructor interaction which refers to the interaction between the student and the instructor; and (c) learner-learner interaction which refers to the interaction between the student and other students. Hillman, Hills and Gunawardena (1994) added a fourth type of interaction, the learner-interface interaction. This is the interaction between the student and the technology necessary for on-line learning. Takimoto-Makarczyk (n.d.) points out that the learner-interface interaction is one of the most valuable types of interaction, especially for on-line education, because this type of interaction is not required in the traditional learning environment.

These are important considerations because on-line students lack the face-to-face contact available in brick-and-mortar classroom environments (Sutton, 1999). As Takimoto-Makarczyk emphasizes, "In the traditional setting, the instructor is physically present with all the learners and can receive immediate feedback through visual or verbal cues. The situation can be quite different in an on-line environment" (p.1). Therefore, interactive learning environments must take into account how students and teachers will use these technologies and how they can support different aspects of interactivity, but the payoff is worth the effort. As Durrington, Berryhill and Swafford (2006) point out, "The research in both traditional and on-line contexts suggests that student interactivity contributes to positive student learning experiences and is a key to effective instruction" (p.190). While interactivity can be achieved with or without a collaboration element, it has become increasingly clear that the inclusion of a collaborative learning component is an important consideration in the emerging paradigm in constructivist learning and these issues are discussed further below.

1.7 COLLABORATIVE LEARNING

Collaborative learning is also not new nor is it particularly difficult to conceptualize and practise. For example, Ng and Ma (2002) report that, "The concept of collaborative learning has been around a long time. Colonel Francis Paker first introduced the concept of collaborative learning in the American public schools system in the late nineteenth century and the concept has further become an active research subject" (p.2). Today, collaborative learning has been especially embraced in higher education. As Delucchi (2006) notes, "In both the sciences and the humanities, faculties have endorsed collaborative teaching modalities at the college level. Collaborative or cooperative learning refers to a variety of techniques involving joint intellectual effort by students" (p.244). While the mechanics involved in collaborative learning are fairly straightforward, the quality of the educational experience afforded by these techniques depends on the students themselves and the skill of the teacher in facilitating collaboration, of course, but by and large there are a number of positive outcomes associate with such collaborative learning techniques. For example, Johnson and Johnson (1994) report that cooperative learning approaches provide a number of positive outcomes, including: (a) improved academic achievement; (b) improved interpersonal relationships among students; and (c) improved attitudes regarding the subject matter being studied as well as the general classroom experience. These positive outcomes are laudable and worthwhile of course, but even more importantly, collaborative learning opportunities also appear to help students become more critical in their thinking and help develop improved problem-solving skills. For instance, in their study, "Collaborative Learning Environments," Ocker and Yaverbaum (2001) make the point that, "Collaborative learning emerges from active learning as a method that develops critical thinking and problem-solving skills, both areas of weakness in traditional educational environments. Collaboration is said to occur when individuals interact with others and exercise, verify, solidify, and improve mental models through both discussion and information sharing" (p.427). In the past, collaborative learning has taken place in face-to-face classrooms of students and teachers; however, the introduction of telecommunications technology has meant that ". . . collaborative experiences can now include anytime/anyplace, asynchronous learning experiences" (Ocker & Yaverbaum, p.427).

For many students today, this shift from a brick-and-mortar classroom to a virtual environment will be a natural and easy one, and where the same types of socialization and interaction can take place. According to "Design for Interaction" (n.d.), "The information technology era provides a new arena for collaborative learning. For students who enroll in on-line courses, the on-line learning environment can be considered as their classroom" where they "interact with the learning material, their fellow students and the facilitator" (p.18). For other students, though, this transition may be more problematic and unnatural and these learners will need more support from the course facilitator. The use of the term "facilitator" in this context is particularly meaningful because it reflects the changing nature of the role played by teachers in these on-line settings, but the need for communication between all participants remains unchanged from one setting to another.

Because some students may feel that they are missing out on some elements of the traditional classroom in these virtual environments, collaboration is key to success. In this regard, "Collaboration not only enhances the learning experience but it also helps to promote the generation of various skills, increase social interaction, increase motivation, and make learning more realistic" (Design for Interaction, p.19). Beyond these significant benefits, students who participate in collaborative learning environments also appear to retain what they have learned for longer periods of time (Srinivas, n.d.). These are clearly valuable educational outcomes, but an effectively administered collaborative learning environment also provides students with even more important skills as well such as promoting "deeper levels of knowledge generation and [the] development of initiative and critical thinking skills" (Design for Interaction, p.19). In sum, the potential benefits of a collaborative on-line learning environment include, but are not limited to, helping students develop an on-line identity and creating an on-line learning community culture; promoting the development of various skills such as critical thinking and problem solving; fostering active participation in the coursework; creating heightened levels of motivation and comfort levels among students; creating a more effective learning environment by helping students achieve positive academic outcomes; and promoting deeper levels of knowledge generation (Design for Interaction). All of these positive outcomes are achievable in a virtual setting that also affords more convenience for students and educators alike than their face-to-face counterparts (Design for Interaction).

Because student-centred instruction is a relatively new approach to the delivery of educational services, some educators may require some practice to refine their techniques and methods. In some cases, "old habits may in fact die hard" and many teachers may be prone to jump in and offer students guidance or solutions based on their traditional and accustomed approach where a more facilitative role would be appropriate in the paradigm emerging today (Kearsley and Shneiderman, 1999). Students must also make extra effort to initiate contacts with peers and facilitators. As Ocker and Yaverbaum (2001) emphasize, "Although collaborative learning techniques have been shown to enhance the learning experience, it is difficult to incorporate these concepts into courses without requiring students to collaborate outside of class" (p.427). The same technology that supports collaborative learning in the virtual classroom can also be used to help students collaborate outside the classroom as well. As Ocker and Yaverbaum note, "Using telecommunications technology can enable students to collaborate on course assignments and projects outside of class, without having to meet face-to-face" (p.428). Such collaborative learning approaches are particularly well suited to the instruction of statistics as well. According to Delucchi (2006), "Most often, collaborative learning group techniques have been recommended to reduce student anxiety and improve statistical skills and knowledge" (p.244).

1.8 DEFINITION OF TERMS

The following terms are used throughout this study. They are defined here for convenience.

Student *attitude* refers to either a positive or a negative opinion of the school and specifically of the Statistics class.

A *browser* is a piece of software which is used to interpret Web pages, Netscape Navigator and Microsoft Internet Explorer are the most popular ones.

A *covariate* is a variable which is significantly correlated with the dependent variable, but not controlled in the design.

Internet refers to the world-wide electronic network constructed by interconnecting the networks of participating countries. It serves as the worldwide information superhighway. The main uses of the Internet include communication via electronic mail, information search, and downloading software and files.

Java is an object-oriented programming language that contains a windows toolkit that was designed to make its applications platform independent. The background and fundamental features of Java are discussed in Appendix A.

A *Java applet* is a small application programme that runs from inside a World Wide Web browser such as Microsoft Internet Explorer or Netscape Communicator. Java applets are created using Java, an object-oriented programming language developed by Sun Microsystems. A collection of Java applets for visualising statistical concepts is illustrated in Appendix C.

Student *performance* refers to the observable and measurable actions that should be demonstrated by the student after completion of the course.

Student *satisfaction* refers to how satisfied the students are with their overall learning experience/the overall quality of the instruction and the course.

Traditional instruction (TI) is viewed as an instructional environment which encourages passive learning, ignores the individual needs of students, and does not adequately assist the development of problem solving and other higher order intellectual skills.

Web-based instruction (WBI), is also known as Web-based training (WBT), Web-based learning (WBL), Internet-based training (IBT), on-line training (OT), on-line learning (OL), e-learning, distributed learning (DL), and advanced distributed learning (ADL). Web-based instruction is instruction which is delivered, in whole or part, using the WWW as the delivery medium. Java applet-based instruction is a special form of Web-based instruction. An exploration of Web-based instruction is presented in Appendix B and strengths and weaknesses of Web-based instruction are also discussed.

World Wide Web (WWW) is an Internet service used for information retrieval. This service takes advantage of the seamless linkage of key terms in a document with related information in other documents. Several Web browsers (also called Web navigators), such as Netscape Navigator and Microsoft Internet Explorer, can be used to navigate the World Wide Web.

1.9 RESEARCH OBJECTIVES

This study was designed to compare Java applet-based instruction and traditional instruction in terms of student performance, student attitude, and student satisfaction. The specific research objectives of the study were:

1. To identify differences in student achievement between the applet and lecture groups.

2. To identify differences in student attitude pre- and post-instruction.

3. To identify differences in student satisfaction between the applet and lecture groups.

1.10 RESEARCH QUESTIONS

1. Is there any statistically significant difference in the performance of students taught by Java applet-based instruction compared with those taught by traditional classroom instruction?

2. Is there any statistically significant difference in student attitude, before and after course completion, for students taught by Java applet-based instruction?

3. Is there any statistically significant difference in student satisfaction for students taught by Java applet-based instruction compared with those taught by traditional classroom instruction?

4. What kind of opinions do the students express about learning by using interactive applets?

5. Why should statistics instructors use applets in teaching? What kinds of advantages and disadvantages appear in learning through interactive applets?

6. According to Khan's WBL framework, does the Java applet-based instructional approach create a meaningful learning experience?

1.11 BACKGROUND

The introductory statistics course within the Computer Studies Programme of the School of Public Administration at the Macau Polytechnic Institute was initially offered in the standard lecture format. Two, 90-minute lectures per week are presented to students using traditional teaching aids such as whiteboard and overhead projector. However, traditional classroom teaching methods utilizing a whiteboard and/or overhead projector with transparencies often fail to convey the key concepts of statistics in a way that is easily understood or remembered by students in a first course.

The course was developing in a stepwise fashion from the standard lecture format to a Web-enhanced instruction format, with the use of Java applets in the classroom. It was envisaged that the change would encourage students to participate in interactive activities and enable learning by visualization and experimentation.

The format of the course was changed to better serve the needs of students with disparate backgrounds and to help them master the concepts and applications of statistics at an advanced level.

1.12 ORIGINALITY OF THE STUDY

The majority of statistics instructors have a high level of mastery over one or more statistical analysis packages including SPSS, Minitab, or SAS. As a result, these instructors have a high level of comfort with applications that are meant for data analysis but not necessarily the teaching of statistical concepts. Instead of making statistical concepts more easily understood they in fact make the entire field more confusing. On the contrary, Java applets, unlike these packages, are designed specifically to help the teaching of statistics, rather than the solving of statistical problems. As Java has become more commonplace and professors, instructors, and software developers have begun to see its benefits for teaching complex subjects, a groundswell of interactive Java applets are beginning to become available on a variety of college and university websites. In fact, a growing set of interactive Java applets are now available on many websites for college statistics courses (Saporta, 1999; Crisp, 2002). These Java applets are giving students the opportunity to learn key concepts interactively. Many of these applets are free for the downloading from the Internet; they stop short of accomplishing the objective of making the complex statistical concepts clear in introductory classes. Clearly, instructors need to consider making their own Java applets for their specific needs.

Of the many uses of Java applets for teaching the more complex and difficult-to-conceptualize topics, statistics is increasingly the area of focus in terms of development. The interactive nature of Java, the accomplishment of its design objectives including portability and scalability, and the responsiveness of the user interfaces of Java allow for quick modeling and scenario testing by students. Java Applets have in fact become the preferred approach as a programming standard over other languages, especially in the development of on-line learning materials for statistics courses.

There is literature and research that explains the learning performance possible with Java applets (Kamthan, 1999), why Java applets are suitable for teaching advanced subjects including statistics (Lock, 1999; Jubran, 2002; West and Ogden, 1998), and the advantages of Java applets over other programming languages (Kamthan, 1999). As of this date, there are no formal research evaluations of Java applets and their effectiveness in the teaching of statistics.

In response to this unmet knowledge need, the main purpose of this study was to create a suite of Java applets, then conduct testing to quantify and evaluate the effectiveness of teaching statistics with applets.

1.13 RATIONALE FOR CHOICE OF SUBJECT

In selecting the subject of statistics for this study, the two main considerations were first that as an academic discipline, statistics involves the exploration and manipulation of data that can be simplified through the use of Java applets, making the students more effective learners in the process. Secondly, by their nature, statistics courses require students to learn entirely new strategies of how to solve problems, in addition to the technologies to support those strategies. This second point could be as simple as trying to use a calculator to perform statistical calculations, or the more challenging aspect of learning how to use statistical software such as SPSS, SAS or Minitab. The progression from calculator, to software, to Web-based applet parallels the development of many other areas of software migrating to the Internet.

1.14 SIGNIFICANCE

The study is significant for several important reasons.

On the one hand, instructors can improve the efficiency and effectiveness of their teaching by using Java applets to explain key statistical concepts in class. The Java applets provide the instructor with a vehicle for showing how something behaved visually and can provide some follow-up examples and answer questions with interactive graphics.

On the other hand, students can develop a deeper statistical understanding by exploring fundamental statistical concepts/principles interactively. The in-class hands-on activities, which include demonstration and/or exercise, allow students to successfully observe and understand. During out-of-class study, students can access these and other applets via the Internet to reinforce key concepts, principles or procedures presented in lectures.

1.15 STRUCTURE OF THE THESIS

This thesis begins with a description of the setting in which this study took place. The objectives of this study, the questions that the study attempts to answer, and definitions of terms used throughout the study are presented in Chapter 1.

Chapter 2 is the Literature Review. It presents the Web-based Learning (WBL) Framework developed by Khan, a review of related literature and previous research in the area of Web-based instruction.

Chapter 3 provides the Research Methodology. The participants who took part in the study, the philosophy and design of the experiment, and the procedures that were followed. Research ethics and validity are discussed. This chapter also lists the methods of data analysis used.

Chapter 4 reports findings and links them with the research questions. Analytic techniques are described here.

The fifth and final chapter is a discussion of the findings, the limitations of this study, and suggestions for future work.

A Reference List and Appendices contain copies of the testing instruments, attitudinal survey, and course evaluation.

CHAPTER 2

REVIEW OF THE LITERATURE

This chapter describes the conceptual framework and presents the related literature. Section 2.1 introduces the Web-based Learning (WBL) Framework developed by Khan. Section 2.2 explores the micro-end dimensions and subdimensions of the Web-Based Learning Framework. Section 2.3 reviews a range of literature related to the area of Web-based instruction.

2.1 CONCEPTUAL FRAMEWORK

It has been well established throughout this study that the role of the Internet and its many publishing mechanisms and protocols are revolutionizing how the world communicates and interacts with one another. The field of Web-based education is arguably by far the most fascinating from the perspective of giving students the opportunity to fulfill their educational objectives. According to Hall (1998), Web-based instruction is "instruction that is delivered via a Web browser, such as Netscape Navigator, through the Internet or an intranet."

A number of learning models can be used to evaluate the effectiveness of Web-based learning. One such model was the Enriched Classroom Model developed by Retalis et al. (1998) which was concerned with using the Web to supplement or enhance traditional classroom instruction. However, this model is too brief and, therefore, not adequate to be directly applied to Web-based learning, because it does not deal with teaching and learning issues that are specific to Web-based learning.

Another learning model, the ADAPT (Active Discovery and Participation thru Technology) Model, developed by Tuckman (2002), was concerned with teaching a Web-based course through a traditional classroom setting. This model combines the essential features of traditional classroom instruction (an instructor and a textbook) with those of computer-mediated instruction (learning by performing rather than listening to lectures, continuous assessment, and immediate feedback). However, this hybrid, Web-based instruction model usually applies to studies with larger sample sizes ranging from 189 to 397 students, and examines group differences by conducting ANCOVA with prior cumulative GPA as the covariate. This wass not feasible with the current study due to its small sample size ($n = 37$ for experimental group, $n = 38$ for control group), and also the inability to retrieve students' past academic records.

As a result, it seemed that the most suitable learning model for Web-based learning is Khan's Web-based learning framework. This was chosen because of its breadth, rigour and comprehensiveness. Khan's framework also provides a useful checklist to help researchers to determine what components and features they may need to put in place for the development of Web-based courses.

The conceptual framework for this current study is therefore based on the framework for Web-based learning (thereafter referred to as the WBL Framework) developed by Khan (1997b). The WBL framework consists of eight dimensions: pedagogical, technological, interface design, evaluation, management, resource support, ethical, and institutional (see Figure 1). Each dimension has several subdimensions (see Table 1), and each subdimension is directly applicable to the role of Web-based instructional strategies. Khan (2001) later offered a framework for placing Web-based instruction along a continuum ranging from "micro" use (using the Web as a way to supplement or enhance conventional classroom instruction) to "macro" use (running complete distance learning programmes and virtual universities) of the World Wide Web. This study is primarily interested in the "micro" end of the continuum and in particular with three dimensions: pedagogical, interface design, and evaluation.

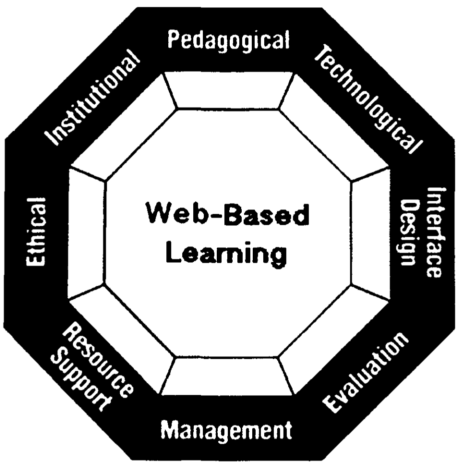


Figure 1:
The Web-Based Learning (WBL) Framework

Table 1: *Dimensions and Subdimensions of the Web-Based Learning Framework*

1. **Pedagogical**	5. **Management**
1.1 Goals/Objectives	5.1 Maintenance of learning environment
1.2 Design approach	5.2 Distribution of information
1.3 Organization	
1.4 Methods and strategies	6. **Resource Support**
1.5 Medium	6.1 On-line support
	6.2 Resources
2. **Technological**	
2.1 Infrastructure planning	7. **Ethical**
2.2 Hardware	7.1 Social and culture diversity
2.3 Software	7.2 Geographical diversity
	7.3 Learner diversity
3. **Interface Design**	7.4 Information accessibility
3.1 Page and site design	7.5 Etiquette
3.2 Content design	7.6 Legal issues
3.3 Navigation	
3.4 Usability testing	8. **Institutional**
	8.1 Academic affairs
4. **Evaluation**	8.2 Student services
4.1 Assessment of learners	
4.2 Evaluation of instruction and learning environment	

2.2 DIMENSIONS AND SUBDIMENSIONS OF THE WBL FRAMEWORK

As previously mentioned, this study is primarily concerned with the "micro" end of the continuum. This is because Web-based applets are used to support what is essentially a traditional face-to-face course.

This study will only focus on the three key dimensions previously identified in the "micro" end of the continuum. The reasons being in Web-based learning (or, more specifically, applet-based learning) the principal components include: the delivery of teaching via the use of interactive and dynamic applets for conveying abstract statistical concepts during in-class demonstration; the design of the curriculum in order to encourage effective Web-based learning; the assessment of student learning and evaluation of the learning process. Thus, the micro-end dimensions to be discussed are: the pedagogical dimension, the interface design dimension, and the evaluation dimension. The remaining five, macro-end dimensions are outlined in Appendix D.

2.2.1 Pedagogical

The essence of Dr. Khan's WBL framework is to put the student at the centre of an integrated, cohesive learning experience. The various dimensions form the foundation for creating a synchronized set of learning strategies and programmes. The development of these synchronized set of strategies are predicated on each of the dimensions of the model component delivering a different aspect of a successful cohesive e-learning strategy. The first of Khan's dimensions to be addressed is pedagogy. This dimension refers to various issues relating to the teaching and learning needs for WBL. In concentrating on the pedagogical dimension the focus is on content analysis, audience analysis, goal analysis, medium and design analysis, organization, and methods and strategies for attaining learning objectives. In speeches regarding his e-learning framework, Dr. Khan concentrates on this specific area as he sees this as being critical to the development of effective e-learning strategies.

2.2.1.1 *Goals/Objectives*

Of the seven key points that comprise the pedagogical dimension, Goal Analysis has the greatest potential for significantly increasing the effectiveness of learning programmes. Setting accurate, attainable and challenging objectives for students of e-learning programmes is critical for their continual growth and development of a more open mindset to learning (Dweck, 2006). Her concepts of an open mindset and challenging objectives, when combined with the concepts of Dr. Khan need to be an area of future research, as her approach to defining challenging objectives is critical to the growth of students.

2.2.1.2 *Design Approach*

If the benefits of e-learning programmes based on the concepts of Dr. Khan's framework are to be realized, the organization or taxonomy of materials and knowledge that comprise any course or learning strategy must be taken into account in addition to the continual adding of new information to broader knowledge taxonomies. These taxonomies are often not as structured as is needed to create e-learning courses and learning foundations from. The gap between the structured needs of the pedagogical dimension, specifically with regard to the points of content analysis, design approach and definitely organization, the role of taxonomies and their relative clarity versus organization is critical. In one case, Jonassen (1997) shows that when problems are by nature more amorphous and ill-defined, the solutions are not as easily discrete and defined. Conversely Jonassen (1997) shows that in those problems that are well-defined and have an element of clarity are inherently bounded with equally definable parameters for answers.

The implications of this from a pedagogical standpoint are that first, when a taxonomy of knowledge is relatively well-structured, the courses based on this knowledge are more amendable to being efficient and streamlined, as their foundational elements are well defined. Conversely when there is little if any taxonomy in place around specific knowledge and a course or entire learning programme is put into place, there is a corresponding lack of course structure and greater difficulty in creating a more enriching e-learning experience for the students. The implication is that the better the organization of the taxonomy, the more valuable a learning experience can be for students as the design approach and organization of the pedagogical dimension of Khan's framework can be put into place.

There are major implications for the design of on-line courseware based on the interaction of the seven points that comprise the Pedagogical Dimension. The greater a taxonomy's structural strength, validity and value as a source of continual learning, the greater the potential of the on-line course in providing students with a more enriching and valuable learning experience.

2.2.1.3 *Organization*

This specific point of the pedagogical model further reinforces how critical it is to first have a solid taxonomy on which to build from in terms of all other points in the Pedagogical Dimension. It could be said that the development of the Pedagogical Dimension is predicated on the relative strength or weakness of the taxonomies that are the basis for each course. From the development of course expectations, learning objectives, and outlines, the depth of organization of the knowledge taxonomy and its ability to be quickly adapted to specific learning strategies and courses is critical.

2.2.1.4 *Methods and Strategies*

In defining the methods and strategies area of the Pedagogical Dimension, Dr. Khan concentrates on twenty different elements to be used in creating an effective and enriching learning experience on-line for students. Looking at these twenty different elements (as is done in this section) requires a perspective of aligning each element to the best possible technological method of delivery for maximum educational value and effectiveness. There is in fact no "one size fits all" approach to automating these twenty elements; rather Dr. Khan suggests in his writings that these form a set of potential tools for creating an optimal learning experience on the part of students. As has been mentioned in other sections, the use of Java-based applets provides an efficient approach to enriching the on-line learning experience while keeping the disruption to on-line networks to a minimum in terms of bandwidth. The following are the twenty attributes that Dr. Khan recommends to create an optimal on-line learning experience.

Presentation as defined by Dr. Khan concentrates on the entire user experience of using the on-line learning applications and tools, including the development and use of on-line metrics to measure learning over time. This attribute is comparable to textbook and courseware production off-line, where the layout, text, and overall look and feel of the book or learning tool is defined. Dr. Khan also defines this attribute as including the many multi-media options available over the Internet as well, and has increasingly focused on these as a means to simplify complex concepts for students.

The *Demonstration* attribute is the level of interaction an on-line learning application or tool has, including its ability to teach students while completing tasks. An example of this would be the use of Java-based applets to draw Normal distribution curves in the middle of a lesson on probability. Increasingly the attribute of demonstration is synonymous to the interactive nature of the application.

Dr. Khan also includes the attribute of *Drill and Practice,* as students learn more through the continual practice and iteration of the steps involved in learning. In academic disciplines that are complex and have deep taxonomies of knowledge including statistics, this attribute concentrates on learning through continual experimentation and testing of concepts. Teaching the concepts of statistics specifically in the area of regression analysis and correlation through JavaScript in conjunction with HTTP support is an example of how this specific element of the Pedagogical Dimension is put into practice.

Tutorials, as the name suggests, is centred on the interactive nature of a learning applications that can traverse the taxonomy of interest and create a series of stepwise on-line learning tools. As has been mentioned by Jonassen (1997) the greater the concentration on a well-defined taxonomy, the greater the learning results, and this is certainly reflected in how much more effective tutorials are when created from a structured taxonomy of knowledge.

As Dr. Khan focuses increasingly on usability, his initial inclusion of *Games* emphasise how even the most complex and structured taxonomies can be made more applicable and useful in the context of learning for the beginner through the advanced student. Games redefine the context of knowledge and lead to greater learning at all educational levels. Games-based learning on WBL for elementary and secondary school students has been introduced for teaching abstract maths concepts, and the development of gaming theory and constraint programming in the development of business strategy courses is becoming increasingly commonplace as well.

Simulations give students an opportunity to learn from making more complex trade-offs and decisions to influence goal-driven scenarios. These scenarios could range from the relatively simple tasks of defining a series of trade-offs in a probability exercise to an assessment of various strategies and their outcomes.

The use of *role-playing* has shown to be effective as an approach to teaching interpersonal skills in addition to assisting students with discovering how their approaches to communicating are perceived. Role-playing gives students an opportunity to simulate the main aspects of how they present information, interpret incoming signals and queues from others, and in the perfecting of social skills. Role-playing is also critical for the development of one-to-one and many-to-one presentation skills as well. Teaching students to quickly interpret social situations and respond to them is essential, and these skills are critical for making the transition into e-learning scenarios. Role-playing learned from in-person interactions is a transferable skill set that can also be used on-line as well.

Discussion, or the process by which students learn through conversations with their instructors, is another of the elements within the methods and strategies section that Dr. Khan makes throughout his framework for e-learning. What's critical is that WBL systems need to be purpose-built to allow for a high level of discussion and interaction between students themselves, and between students and instructors. A unifying attribute of the entire Khan e-learning framework is in fact collaboration. As is the case with the best modes of communication, there needs to be a concentration on creating one that is both asynchronous, or when communication is sporadic and driven by the sender and receiver. There also needs to be support for fully synchronous levels of communication as well, as in this model the e-learning system needs to support the development of highly interactive forums within which students can share insights amongst themselves in addition to sharing information and posting questions for instructors as well. The collaborative objectives of any on-line discussion forum need to centre on supporting both asynchronous and synchronous communications as well to be effective in serving the many unmet needs of students and instructors. Fulfilling the objective of creating and managing both moderated and unmoderated discussion forums, including those defined through subject-related and courseware-related design criteria, the development of a WBL system to respond to these unmet needs is critical if students are to attain the objectives they need to accomplish, both in passing the class and also in retaining more for their long-term professional growth. Examples of asynchronous or sporadic communications in the context of WBL systems include discussion and dialog forums, newsgroups, or even the development of share folders and e-mail mailing lists. Increasingly WBL systems are concentrating on the use of highly interactive two-way communications that have become more widespread globally as broadband Internet permeates learning-centric regions of the world. Synchronous communications provide for real-time, interactive communications globally, and are designed for the relatively low-end levels of text messaging to the mid-range interactive chat sessions, to the use of real-time video feeds from a student's personal computer to the instructor for purposes of completing an on-line class or a one-on-one tutorial on one aspect of the courses' content. This is one area of the Khan Framework that will continues to gain momentum throughout the next five years as broadband Internet accessibility becomes more pervasive globally.

Interaction is the characteristic of an e-learning system to be responsive to the inputs and navigation of the users of the system. Just as is the case with the development of computer software or the development of navigation screens on personal electronics devices, the attribute of being highly interactive is critical for users to be able to learn quickly how to use the device. As is the case with many of the concepts defined by Khan in the creation of his e-learning framework, the need for integrating with other points in the model is paramount. This is certainly the case with *Interaction*, which is pivotal in the development of pedagogically-based teaching strategies. The attribute of *Interaction* also can be evidenced in varying degrees; it is not a binary state but rather one that is present in the graphical interfaces, mechanisms for managing navigation, and the development of non-linear approaches to defining learning strategies.

Modelling is as Khan defines it in the context of his e-learning framework, is an approach that relies on providing a foundation or defining a standard to which students can aspire to. The interesting interpretation of this factor by Khan is that it centres on the development of modeling from the context of setting both communications and deliverables learning-based objectives for the student. In essence Khan is saying that the development of modeling provides a strong foundation for students to visualize the result they want to achieve, both from a communications-based and results-driven approach to their studies. In the context of teaching a course that is highly conceptual and abstract in concepts, the use of modeling is highly effective in defining how the fundamental concepts of probability can be applied to practical problems in business for example. The definition of correlation and regression in statistics, inherently complex and abstract by nature, could potentially be taught more efficiently through modeling as well.

Bringing together students and mentors, both on-line and face-to-face, is essential to facilitating greater understanding and insight into material covered in a course. Khan defines *Facilitation* as having the ability to use a WBL-based system environment to create a higher level of coaching both one-on-one and through the use of one-to-many discussions as well. As e-learning systems need to compensate for the approaches and styles of communicating that students find the most effective and useful, facilitation as a component needs to support both asynchronous and synchronous communications styles for an e-learning system to be effective.

Central to the development of any effective e-learning system and arguably a main component of Khan's e-learning framework is the component of *Collaboration*, which is the hallmark of constructivist learning theory. Khan has often remarked in his research and presentations that this specific component is what unifies the entire framework and leads to greater levels of velocity over time in terms of communications and learning. Collaboration is critical for enabling communications between students themselves and their instructor. There are also WBL systems that provide for collaboration from students and previous instructors as well, enabling a greater breadth of learning and perspective on the subjects being studied. Khan differentiates between internally- and externally-based collaboration as well, and the design of WBL systems also concentrates on using collaboration in conjunction with interactivity to enhance the overall learning experience.

Field trips are virtually hosted by instructors to present students with perspectives, examples and applications of the knowledge being learned. WBL teaching strategies based on Khan's e-learning framework focus also on guiding students through a series of on-line learning exercises that include a variety of on-line resources including databases, websites, and the use of interactive teaching tools.

Khan's inclusion of *Apprenticeships* within the framework and specifically in the Methods and Strategies area acts as a catalyst to use the other elements or attributes as well, specifically concentrating on collaboration and interactivity. Apprenticeships are facilitated through e-learning by introducing students to those in professions of interest.

Teaching through *Case studies* is one of the most common approaches to teaching situationally-based lessons, including the application of key abstract concepts. As WBL systems are focused on teaching students through the learning channels that align with how they prefer to learn, case studies presented through e-learning applications vary in their approach to interactivity and collaboration. Khan's e-learning framework research has shown that the use of case studies as the basis of discussions and debate on-line and for the illustrating of concepts that are best taught in a situational or case-based format.

The concept of *Generative Development* as defined by Khan is specifically focused on the development and continual refinement of knowledge taxonomies. The continual growth of WBL-based systems needs to concentrate on adding as many inbound sources of information and data to continually strengthen and extend the taxonomy of knowledge for a given project. In conjunction with the development of these knowledge taxonomies that by default must also be able to "learn" over time, there is also the need for specifically focusing on how to create agile enough taxonomy frameworks to take into account variations in the data and information. Khan indicates in his research that the development of agile taxonomies are essential for creating a foundation in WBL systems that provide for enough flexibility to respond to changing requirements of students and instructors.

When all the methods and strategies points are coordinated with one another in the design of a WBL system, and there is a high level of collaboration achieved among students and between students and instructors, in addition to there being a high level of trust evolving over time, *Motivation* to excel in learning begins to take place. The foundation of any effective WBL system is the ability to successfully motivate students to do the best job at working to understand the material, having an appreciation for its specific taxonomies and structures, and looking to see how to identify and internalize the knowledge presented in the course and overall learning experience. Cornell and Martin (1997) have found through their empirical research that the critical criteria in building

WBL systems and courses are those that provide active and positive cues to learners. The use of effective interactivity techniques and courseware design is important in creating a learning environment that also allows students to also to set their own objectives and pursue their own goal attainment.

2.2.1.5 *Instructional Medium*

The Web is the communication medium for Web-based learning. To ensure an effective Web-based learning environment, its attributes as a communication medium must also be kept in mind.

2.2.2 Interface Design

The second dimension of Khan's framework to recognize is the interface design dimension. This dimension refers to various issues regarding the overall look and feel of WBL programmes.

In defining the e-learning framework, Dr. Khan envisioned that many of the components that comprise the Methods and Strategies area of the Pedagogical Dimension would be highly collaborative in nature. This is certainly the case with the Interface Design aspect of WBL systems development. One of the greatest challenges of interface design is in making the entire series of computer screens that comprise the applications easy to use and intuitive. The greater the ease of navigation and intuitiveness, the higher the level of use or adoption on the part of students. When interface design is done well it leads to a higher level of collaboration through higher adoption, or use, of each application. The term usability refers to a set of attributes and characteristics an interface either has or doesn't have. Page and site design, content design, navigation, well-defined links, a logical progression of screens, support for multiple approaches to navigation, and support for a variety of personalization options to enrich the learning experience are all considered part of a successful interface design. The components of page and site design, content design, and navigation are discussed in this section.

2.2.2.1 *Page and Site Design*

Page designs are the building blocks on which a WBL system creates applications that have high levels of usability, and promote collaboration. The use of design standards to ensure pages are accessible, understandable and usable by the most experienced of WBL system users to those just beginning to work with applications is critical. The challenge of effective page design is to appeal to and provide the functionality necessary to support these two opposite ends of the experience spectrum of users. In addition to supporting these wide variations in users' specific levels of knowledge, there is also the need for creating application pages that specifically focus on how to increase the level of initial application use and further comprehension of the materials covered throughout an e-learning course. Increasingly educators are combining the use of graphics and highly efficient programming languages including Java to enrich the on-line learning experience for students taking courses via a WBL system. The combining of graphics, navigational approaches to organizing content, and the integration of content from knowledge taxonomies into lessons students can comprehend in timeframes that match their schedules is a one of the practicality goals of page and site design. In conjunction with these considerations is the need to design both web pages and entire sites to be accessible to those with handicaps as well. The world's most commonly used set of standards specifically for this purpose, and for the broader considerations of designing Web-based applications is the use of the WC3 (The World Wide Web Consortium) guidelines. This standards body often works in conjunction with other standards organizations including the Centre for Applied Special Technology. The purpose of this organization is to provide expert-level guidance in the development of Web-based applications and tools for those Web users who handicaps or a disabled and have difficulty interacting with WBL systems through common interfaces.

2.2.2.2 *Content Design*

According to the work completed by Khan in constructing his e-learning framework, the development of scalable yet agile taxonomies for knowledge is at a comparable level of importance to the level of collaboration possible within a WBL system. Khan's prioritization of elements in his e-learning framework centre on enriching the learners' experience, including the effective presentation of content emanating from a well-thought out and hopefully time-proven taxonomy of broader knowledge. Content design then is the link between the taxonomy of knowledge on the one hand and the presentation of the content on-line on the other. Nielsen (2000) has emphasized that the design criteria and interface standards need to have a high level of consistency and congruency to standards if effective learning is to take place. This is a factor that transcends the type of font used, to including the entire concepts of the content being accurately defined within the applications' pages and throughout the entire WBL system itself. Over and above the aesthetics of any given page, there is the more critical concern of ensuring the taxonomy of knowledge being presented in the WBL system is consistently defined and represented in the context of applications.

2.2.2.3 *Navigation*

As with many concepts in the Khan e-learning framework, this specific factor in the Interface Design Dimension of his e-learning framework is based on the successful integration and synchronization of several other components and dimensions as well. Navigation is the by-product of having a highly interactive, facilitative, and increasingly role- and knowledge-level based to support scaffolding teaching strategies in conjunction with WBL-based learning strategies. Navigation is highly dependent on these factors in addition to the level of interaction and usability designed into the web pages and the WBL system itself.

In designing a WBL system, the factors of usability, interactivity, collaborative use of applications between students and instructors, and the development of roles-based navigation through pages, applications and the entire WBL system is critical. Navigational excellence of any WBL system is a complex goal to achieve as it requires a high level of synchronization across many different elements, points and Dimensions of the Khan e-learning framework.

2.2.2.4 *Usability Testing*

Creating web pages and applications that are usable and accessible by a wide variation of students in terms of their abilities and previous experience working with Web-based applications is what Khan intended by including this component in the Interface Design Dimension of the e-learning framework. Microsoft, SAP, Oracle and other enterprise software companies are relying on usability testing to ensure their applications are usable by their customers, across a wide variation of process workflows that correspond to customers' goals and strategies. The need for WBL systems to specifically have usability designed in as a key attribute has been discussed by Reeves and Carter (2001). Their collective research shows that WBL system administration functions in addition to the applications' pages and navigation have been tested for usability. According to Nielsen (2000), there is an increasing focus on usability standards testing on a global level as many distance learning strategies based on WBL systems and platforms are now serving students in multiple nations at the same time. The global reach of WBL systems makes global usability standards a necessity.

2.2.3 Evaluation

The last applicable dimension of Khan's framework, evaluation, is addressed through the guidelines for assessing student learning and instructional quality.

Khan's e-learning framework is designed to continually improve the e-learning experience of students. The inclusion of the Evaluation Dimension plays a pivotal role in providing the feedback necessary to continually fine-tune e-learning strategies supported using the network. Khan has defined the points of assessment of learners and evaluation of the instruction and learning environment as two key aspects of the Evaluation Dimension. Each of these factors is explained below.

2.2.3.1 *Assessment of Learners*

For any e-learning series of strategies and programmes to improve in its service to students, there needs to be a periodic measurement of how effective the e-learning environment is in assisting students to learn more. This first point of the Evaluation Dimension, assessment of learners, concentrates on testing the effectiveness of e-learning programmes in providing students with knowledge they can retain. Khan has suggested that measuring the performance of learning across multiple choice, true/false, essay and logic tests partially measures learning. Measuring the application and use of concepts is another critical aspect of the assessment of learners.

2.2.3.2 *Evaluation of Instruction and Learning Environment*

Improving the performance of instructors through the generating of feedback and use of incremental training is also critical if any e-learning teaching strategy is to stay effective. As with other areas of the Khan e-learning framework, the use of instructor feedback is also critical the continual improvement of e-learning strategies and the increased effectiveness of e-learning as a teaching strategy overall.

2.3 RESEARCH ON THE IMPACT OF WEB-BASED COURSES ON STUDENT PERFORMANCE, ATTITUDE AND SATISFACTION

This section synthesizes the research that has been conducted on the impact of Web-based learning on student performance, student attitude, and student satisfaction. The review encompassed 63 articles published between 1983 and 2005. While Statistics is the main academic discipline of this particular research study, the scope of this literature review is expanded to research regardless of the specific academic discipline.

Solving the critical problems of higher education through the use of technologies is gaining widespread interest. The Internet specifically is gaining a significantly high level of interest; both as a learning tool and foundation for teaching tool as well (Green and Gentemann, 2001). Instructors are increasingly finding that students' familiarly and expertise using the Internet can be capitalized on to strengthen their learning experience. The combining of on-line and in-class discussions is proving to be a highly effective teaching strategy, which is often perceived very positively by students as well. When course materials are presented in a selection of formats, students learn and retain knowledge more efficiently and permanently as they have the opportunity to choose from which format they are most adept at learning from (Clark, 2003).

Of all formats for teaching materials, the Internet has become the easiest to use from an instructor publishing standpoint, and the most pervasive, easily accessed and used for reinforcing learning from a student standpoint. By definition a "Web-enhanced course" distributes course materials using the Internet, providing students with on-line resources (Boettcher, 1999). The use of the Internet as a teaching platform has given many lecturers and professors the opportunity to introduce more interactive learning tools that make it possible to retain students' attention for longer periods of time, ensuring they gain a total understanding of a concept discussed in class. The Internet, with its ability to provide for the presentation of a wide variety of on-line presentation techniques and approaches, is resulting in a significantly higher level of student motivation and attentiveness to the concepts presented (Basile and D'Aquila, 2002).

For the purposes of this review, Web-based instruction is considered to be any educational or training programme distributed over the Internet or an intranet and conveyed through a browser, such as Internet Explorer or Netscape Navigator. Java applet-based instruction is a special form of Web-based instruction.

So far, there is very little research on comparing the effectiveness of Java applet-based instruction to the traditional face-to-face offering. However Web-based instruction has received sufficient attention that many studies are now available in the research literature.

Comparing the learning effects of Web-based learning with traditional face-to-face teaching and learning is emphasized in the research on the Internet as a medium in higher education. However, these research studies invariably produce conflicting results in relation to student learning outcomes (e.g., performance, attitude, satisfaction). Some studies showed differences favouring Web-based courses (Agarwal and Day, 1998; Al-Jarf and Sado, 2002; Clark, 2003; Day, Raven, and Newman, 1998; Despain, 1997; Dewhurst, Macleod, and Norris, 2000; Driver, 2002; Dutton, Dutton and Perry, 2001; Enockson, 1997; Felix, 2001; Goolkasian, 1989; Hughes and Hagie, 2005; Jordan, Smith, Dillon, Algozzine, Beattie, Spooner, and Fisher, 2004; Karuppan and Karuppan, 1999; Kulik, 1994; Liu, 2005; McCreanor, 2000; Navarro and Shoemaker, 2000; Schutte, 1996; Spivey, 1983; Summary and Summary, 1998; Ware and Chastain, 1989; Yu and Yu, 2001).

Some showed differences favouring lecture-based courses (Debourgh, 1998; Faux and Black-Hughes, 2000; Johnson, Aragon, Shaik, and Palma-Rivas, 2000; Maki, Maki, Patterson and Whittaker, 2000; Rivera, McAlister and Rice, 2002; Sole and Lindquist, 2001; Wang and Newlin, 2000; Waschull, 2001; Welsh and Null, 1991).

Many studies showed no differences at all, i.e., no learning preferences for on-line or traditional method of instruction (Caywood and Duckett, 2003; Fallah and Ubell, 2000; Green and Gentemann, 2001; Johnson, 2002; Johnson, Aragon, Shaik, and Palma-Rivas, 2000; Jones, 1999; LaRose, Gregg, and Eastin, 1998; Petracchi and Patchner, 2001; Rivera, McAlister and Rice, 2002; Ruchti and Odell, 2001; Russell, 1999; Ryan, 2000; Sandercock and Shaw, 1999; Sankaran and Bui, 2001; Schulman and Sims, 1999; Skylar, Giggins, Boone, Jones, Pierce and Gelfer, 2005; Spooner, Jordan, Algozzine, and Spooner, 1999; Steinweg, Davis and Thomson, 2005; Stepanovich, 2002; Thirunarayanan and Pérez-Prado, 2002; Wang and Newlin, 2000; Waschull, 2001).

Three dominant themes are being explored here. The first theme is to explore student performance, the second theme is to examine student attitude, and the third theme is to focus on student satisfaction.

Student Performance

Some studies found Web-based learning had a positive effect on students' performance. To date, the most methodologically sound investigation to evaluate the effectiveness of on-line instruction was conducted by Schutte (1996). Using a Social Statistics course as the sampling frame, Schutte completed his empirical study in the course taught at California State University, Northridge. To complete the research, Schutte randomly divided thirty-three students into two groups. The first group would be taught using traditional face-to-face instruction method while the second would be taught via the Internet. Text, lectures and examinations were standardized across the two groups. This second set of students was considered by Schutte to be his "virtual set" as it was completed entirely via the Internet. Both groups were given identical mid-term and final examinations. The results of the examinations showed a 20% increase in the performance of the virtual class.

Numerous studies were described below which have also supported the significant increases in learning outcomes for on-line learners over their traditional counterparts.

One of the more ambitious and comprehensive research studies which was completed quantified students' performance using a state-of-the-art WBI course compared with a traditional two-semester course to teach Economics (Agarwal and Day, 1998). Like Statistics, Economics is highly conceptual in nature and benefits significantly from interactive examples to simplify complex concepts. The WBI course relied on e-mail and mailing lists to respond to students' inquiries on the materials, and also to create a collaborative on-line learning environment for all students enrolled in the on-line course. In addition, the Internet was used as a platform and specific websites were used to provide students with access to assignments, syllabi, schedules, and projects, all aimed at giving the students all the information they needed to complete the course. The findings quantified that the use of WBI for teaching two semesters of Economics had a significantly positive influence on students' learning. The results of this study showed significant performance gains for the on-line students on both examination scores and final grades, when compared to the control group.

In another study which focussed on the performance of students in technical writing in an undergraduate agricommunication course, Day, Raven, and Newman (1998) compared a traditional class (learning without a laboratory) to a We-based class (learning with a laboratory). Two applications questions (writing a memorandum and editing a business letter) on the mid-term examination and the major class project were used to measure students' achievement. They found that the on-line students attained significantly higher achievement scores than those in the traditional course.

Navarro and Shoemaker (2000) compared and studied the effects of Web-based versus traditional face-to-face instruction on students' performance in an introductory economics course. Those students in the Web-based course were given the lecture content through e-mails, on-line presentations, supplemented with CD-ROMs for off-line viewing, electronic bulletin boards, and extensive availability of on-line chat rooms for interactive discussions with other students and the instructor. These chat rooms provided a much higher level of collaboration than was possible in a traditional face-to-face classroom teaching scenario in that it gave each student the flexibility of communicating at the time of the day most convenient to them. Comparing the performance of each group, those students in the Web-based course achieved significantly higher grades on both their finals, and also illustrated that the higher the level of collaboration between students and also between students and their instructor, the higher the overall performance of the class.

Teaching computer languages over the Internet, using WBI, can leads to significantly higher levels of performance, as the research work of Dutton, Dutton and Perry (2001) illustrates. The researchers compared WBI-based teaching with traditional face-to-face lectures, and found that the WBI-based students did significantly better on assignments, tests, and the final examination. As this course required much programming and use of computers, those students taught through WBI were able to capitalize on their knowledge of computers and the Internet to learn and retain key concepts. In this instance, the students were able to progress through the materials at their own speed, keeping up their interest, challenging them in the process and ultimately leading to higher levels of satisfaction and performance.

In addition to the empirical study of Web-based learning on students' performance, researchers have also been evaluating these teaching methods in the context of teaching instructors how to teach using these methods. Yu and Yu (2001) completed a study that divided 68 pre-service teachers in a Computers and Education course into two groups. The researchers had the first group use e-mail as the mode of communication for supplementary materials, while the second group of pre-service teachers did not. The result shows that those students in the group using e-mail achieved higher levels of performance than that achieved by the non-e-mail group. While the study's findings support other empirical research studies of how electronic mail and other forms of Web-based learning can significantly increase performance through greater collaboration, this specific study did not first capture a pre-intervention measure of performance. The researchers needed to have measured the performance of the groups prior to the introduction of e-mail as a communication and collaboration approach for the results to be empirically sound and valid. Nonetheless, the study does show that even for teachers as peers, the need for collaboration through the use of e-mail and other electronic means of communication is critical for their success.

In teaching two groups of freshmen students ESL writing fundamentals in a writing course, Al-Jarf and Sado (2002) designed their methodology to include Web-based and traditional groups. The experimental group was based entirely on Web-based instruction while the control group was taught through traditional face-to-face in-class instruction methods. The results showed that the students taught through the Web-based course had greater gains in writing, made fewer errors, communicated more fluently and with less hesitation and greater confidence, and also scored higher on tests than their in-class taught counterparts. From this study it appears that teaching a secondary language requires a high level of repetitiveness and also collaboration between students and instructors to ensure the highest level of learning performance is achieved.

Teaching the concepts of "attention deficit disorder" (ADD)/"attention deficit hyperactivity disorder" (ADHD) in a graduate-level learning disabilities class also provides insights into the effectiveness of on-line compared with traditional face-to-face classroom instruction. In completing this study, Jordan and colleagues (2004), designed their methodology to include both the students taught on-line using WebCT-based technologies compared with a control group taught using traditional in-class face-to-face instruction. The researchers provided a self-reporting survey to both sets of respondents, asking each group to evaluate the effectiveness of each course's teaching strategy and results gained. Those students in the on-line WebCT-based course reported significantly greater knowledge of ADD/ADHD concepts, an improvement in skills for teaching learning disabilities, in addition to a significant improvement in technological and Internet-based learning skills as a result of using the on-line tools.

Some studies also showed that Web-enhanced learning (with the course materials being available on the Web in addition to face-to-face instruction) was positively related to students' learning outcome. McCreanor (2000) conducted a study in a solid waste management course and found that the use of Web-enhancements had a very positive effect on the course. When students were given Web-enhancements to prepare for learning sessions, they arrived for class sessions better prepared and more adept at understanding the illustration of concepts in the class. Retention of course materials was also significantly greater for those students who used Web-enhancements and also lead to less preparation time for examinations as well. Students using Web-enhancements also reported that the ability to creatively apply concepts from the course also increased as a result of the use of Web-enhanced learning.

In addition to the ability of Web-enhancements to simplify complex concepts and also foster higher levels of collaboration between students and with instructors, the research completed by Clark (2003) emphasises both of these findings. In this researcher's study the methodology included the study of three-semester length courses which had a large percentage of mathematical concepts and content. Clark found that the overall performance of the class increased significantly as a result of having class lectures notes available on-line, in addition to the ability to comment on the notes on-line, creating a collaborative forum for everyone in the class. Clark also found that the students who had the on-line notes available, including the ability to comment on them, performed significantly better than those that did not have these on-line tools available.

The examined literature clearly indicates that a mainly positive performance outcome can be expected from either wholly or partially including WBL strategies in a variety of different subject areas. In order to illustrate this in more specific terms, three dimensions of Khan's WBL framework are used: the pedagogical, the interface design, and the evaluation dimensions.

In the Pedagogical Dimension, Agarwal and Day (1998) note that education and communication technology studies indicate the success of WBL strategies specifically in terms of interaction and the hands-on learning of new concepts. Interaction, discussion, research, and transmission of information are all enhanced via the on-line environment, mainly because there are no time and space restrictions involved. Furthermore, student-teacher interaction is enhanced by the on-line environment, because the uncertainty factor of communication is significantly reduced: students are not intimidated by the physical presence of the teacher or other students. Specifically, the authors address the enhancement of learning in the field of economics. In this complex subject area, the authors hold that performance is enhanced resulting in outcomes such as critical thinking, problem solving, and autonomy, as a consequence of more interaction among students and between students and teachers. These outcomes are all enhanced via the on-line environment that facilitates not only information retrieval, but also encourages more frequent communication. This translates to a higher level of learning and retention of complex economic concepts, according to the authors (Agarwal and Day, 1998).

In examining writing instruction in the EFL classroom, Al-Jarf (2002) also finds favourable results from including Web-based instruction for students. Al-Jarf's study uses a combination of Web-based and in-class writing instruction. According to the results of the study, such a combination proved significantly favourable for the final results of the experimental group as opposed to the control group.

In addition to communication and interaction issues, other pedagogical elements that serve as an advantage for the on-line learning environment include the continuous visibility of and accessibility of lecture notes, homework, calendars, and handouts (Clark, 2003).

For the Interface Design Dimension, the on-line environment also lends itself to significant advantages in terms of interface design. Elements that are for example not mentioned regularly in the traditional classroom can be prominently linked to on-line learning material. These include the name and contact information of the lecturer, recommended texts, the grading scheme, cheating policies and the expected workload and course goals which tend not to be mentioned on a daily basis in the face-to-face class setup (Dutton, Dutton and Perry, 2001), for example. These can serve as an advantage to the student by being prominently linked to the material the student is working with, and enhance performance. The availability of lecture notes also provides the student with the opportunity to repeat whatever information is unclear or technically difficult, without impacting upon lecture time.

In the Evaluation Dimension, according to Agarwal and Day (1998), instructor evaluation forms in terms of the on-line environment yielded generally positive results: students reacted positively towards instructors and the learning materials.

The same is true in terms of student assessment in the form of homework, quizzes and tests, as investigated by Clark (2003). The results of these generally compared positively to those of the control group in the traditional, face-to-face class environment, and few comments were needed on submitted material.

In contrast to studies yielding positive results, a few studies, described below, have shown better performance in lecture-based courses. One of the research studies completed by Welsh and Null (1991), which investigated the use of lecture-based and Web-based instruction for instructing students how to create research designs revealed that traditional methods were actually superior to those students who were taught the identical materials over the Internet. As research designs are taught in a highly collaborative approach, the results of this research have been refuted as showing that collaboration, even on-line, has room for improvement.

A second study which revealed contrary results to the positive impact of Web-based teaching strategies is also provided by researchers Wang and Newlin (2000). These researchers employed the common methodology of dividing students into Web-based compared with traditional lecture-based face-to-face teaching. The course content was a statistical methods course. Comparing the performance of each sample of students showed that the performance of the lecture-based students was more superior on the final examination.

Another study centred on the teaching of an introductory course in psychology, where the methodology also included a comparison of Web-based sections with in-class lecture samples (Waschull, 2001). The students were given the opportunity to join which sample group, making the methodology a self-selected one. What this researcher found was that there was a significant difference in the final examination. The mean performance was higher in the lecture-based classes than the Web-based classes.

Studies also abound demonstrating "no significant difference" in student performance in traditional and Web-based college courses. Jones (1999) conducted a comparison study and found no significant difference in grade point average (GPA) between students in an all Web-based class and traditional learners. In a study that compiled 50 years of research comparing various methods of instruction, Russell (1999) found no significant differences in academic performance of students when looking only at the instructional methods. Using the post-test scores to evaluate the performance between Web-based compared with traditional face-to-face instruction of undergraduate students also showed no statistically significant difference (Schulman and Sims, 1999).

The same result was found by Sandercock and Shaw (1999), who sampled from a WBI-based and traditionally-taught undergraduate course in Sports Science. Using examination results and course work to evaluate the performance of both samples of students, Sandercock and Shaw found no statistically significant difference in student performance. Learning outcomes from traditional face-to-face teaching where on-campus attendance was required compared with those students who were taught entirely over the Internet produced little or no difference as well (Fallah and Ubell, 2000). In teaching construction and methods classes no significant differences in performance were found between traditionally taught students and their Internet-based counterparts (Ryan, 2000). Contrary to the earlier-quoted research showing the effectiveness of teaching ESL classes on-line, Green and Gentemann (2001) found no statistically significant differences in teaching an English course through traditional face-to-face approaches compared with using Web-based approaches. Both course grades and the retention of material, when tested for statistical significance, showed no significant differences. Johnson (2002) also found that there was no significant difference in performance in an introductory biology class between on-line and off-line students.

Several other studies have found no differences in learning outcomes in various courses involving on-line and traditional learner. When distance learning techniques were evaluated compared with traditional face-to-face instruction for high school students taking an advanced mathematics course, there were no significant differences in student performance (Ryan, 1996). It is noteworthy that Ryan found that those students taught through distance learning compared with traditional means accomplished the same level of learning performance, denoting that high achievement was possible for students in either sample group.

Using a graduate-level Human Resources (HR) development course, researchers Johnson, Aragon, Shaik, and Palma-Rivas (2000) defined and executed one of the most thorough methodologies to date that showed no differences between those graduate students taught through traditional compared with Web-based methods. The researchers took much effort to ensure that all aspects of variability in performance were taken into account. Using a pre-test/post-test methodology, all students were first tested at the beginning of the course as to their existing level of knowledge on key concepts in the course. In addition, the demographics of each sample were captured before the course began, noting the age, year of graduation, years of work experience, and level of academic and professional achievement. The researchers completed extensive cross-groups statistical analysis to see if there were any pre-existing statistical differences in their knowledge of HR concepts prior to the class, and none was found. With the prior performance and existing levels of all respondents normalized, the researchers next initiated the course and periodically tested the performance of each respondent sample. During interim testing and final examinations, no significant differences were found in the academic performance of each respondent group. This led Johnson, Aragon, Shaik, and Palma-Rivas to conclude that there was no significant difference in Web-based compared with traditional in-class face-to-face instruction.

A unique research project by Petracchi and Patchner (2001) measured the effectiveness of traditional teaching approaches in class compared with those offered through an interactive television approach. The remote-based training of students through the use of interactive television yielded no significant variation in performance compared to their traditionally-taught counterparts.

Providing insights into traditional compared with on-line training techniques in teaching pre-service teachers about the subject of Elementary Science Teaching Methods, Ruchti and Odell (2001) randomly assigned 79 students to traditionally-based compared with on-line study groups. The researchers considered the on-line respondent group the experimental group, and completed their modules entirely on-line, including collaboration, evaluating and testing. In contrast, the control group was those students taught entirely in class through traditional face-to-face methods. To minimize any variability inherent in the randomization of respondents, the researchers completed a series of pre- and post-test evaluations to ascertain the level of science knowledge by respondent. Taking into account these factors, even with the randomization of respondents across groups, the research yielded no significant results when on-line compared with traditional teaching approaches were taken into account.

Further research into the inconclusiveness of Web-based compared with traditional teaching techniques yet supporting the finding that the higher the level of student motivation, the higher the performance regardless of course delivery approach was supported by the research completed by Sankaran and Bui (2001). The basis of this research team's study centred on the performance of students enrolled in a business course. A total of 116 university students, were randomly assigned to one of two specific course sessions, which were Web-based and traditional in-class face-to-face based. The researchers completed only slight modifications to the course content, formatting lectures, notes and presentations only slightly to be compatible with Web-based presentation standards. To further account for any potential variability between groups, the research team completed both pre- and post-test screening of all students in terms of previous business experience and knowledge of concepts. The results showed that while performance between Web-based and traditionally taught courses showed no significant difference, the relative motivation of students in either group was the best predictor of success. With only slight modifications to course content for the Web and with pre- and post-test control of variability in place, this study provides a useful foundation for illustrating how Web-based tools alone cannot compensate for a lack of motivation of students, regardless of the method of teaching completed.

The inconclusive nature of Web-based training compared with traditionally-based approaches is also emphasised in a study completed by Rivera, McAlister and Rice (2002), which developed a methodology that had three groups included within it. The first was a group of students who were taught entirely via the Internet using a WebCT courseware, the second were taught entirely in traditional in-class sessions, and the third were taught in a hybrid approach of both Web-based and in-class training. Of specific interest was the fact that the study focused on an introductory management information systems course, which by its content, was well suited to being taught on-line. The researchers assigned 45 students to each of the three groups, and through statistical analysis found no significant differences in performance across the three groups.

Another study which included the combination of Web-based training, traditional in-class instruction or the use of television as a teaching medium also showed no significantly different results between each approach (Stepanovich, 2002). The results of a longitudinal analysis of 917 students at California State University, Bakersfield completed by Carlisle in 1998 showed that significant learning advances were made by students, regardless of the teaching approach used. In addition, this longitudinal study also found that Web-based learning approaches, when the materials were specifically tailored for the Web, did produce slightly higher level learning, yet the results were not statistically significant compared to the other approaches measured in the study.

Contrary to the earlier study that showed how ESL courses can be successfully taught via the Internet, Thirunarayanan and Pérez-Prado (2002) created a robust pre- and post-test research design where they measured all students prior to the class, in addition to comparing the mean score of students' performance across both sections. Moreover, the researchers also completed analysis in post-test, again looking for statistical significance across both sets of respondents. In the pre-test statistical analysis, those students in traditional courses had a better performance than their on-line counterparts. However, on the post-test, the researchers found no significant differences between the groups. The on-line students, while having lower initial scores in the pre-test, advanced at a statistically significant faster rate.

In a graduate-level course on special education teaching strategies, Caywood and Duckett (2003) measured the performance of students taught on the Internet, via an e-

College Internet application. Academic performance was measured on three multiple-choice quizzes delivered both on-line and also on campus. The researchers also reported no significant differences in the learning performance of either the Web-based or on-campus equivalents. Also in the area of special education courses, Skylar and colleagues (2005) devised a research strategy for comparing learning effectiveness using on-line instruction using WebCT, traditional classroom instruction, and class-in-a-box multimedia kits that included CD-ROMs. In addition, the researchers completed a pre- and post-test analysis of learning levels, and found that despite the variation in each teaching technique, there was no significant difference in learning performance.

Also using a special education course as the basis for comparing the performance of on-line and traditional in-class face-to-face instruction methods, Steinweg, Davis, and Thomson (2005) relied on the On-line Digital Blackboard system prevalent in McGraw-Hill Advanced Education Programmes, which includes a broad array of content and useful third-party research for students. The researchers ensured that all aspects of both the on-line and face-to-face programmes were identical to one another. The researchers also completed a pre- and post-test analysis of student scores between each group on class projects, and found no significant difference between either teaching approaches.

Student Attitude

In addition to grades as indicators of learning success, student attitude may be equally important.

Some studies show differences which favour Web-based courses. Kulik (1994) conducted a meta-analysis on computer-based instruction and found that those students receiving computer-based instruction showed a more positive attitude that led to learning more in less time and the development of more positive attitudes about the course material specifically and on-line learning overall. This attitudinal research showed that students who could accomplish a faster learning pace had significantly higher levels of attitude with their learning experience. In addition, students in an undergraduate technical writing module of an agricommunication course also scored higher mean levels of attitudinal gains in seeing writing as a valuable skill when taught on-line compared with traditional in-class face-to-face methods (Day, Raven, and Newman, 1998).

There is also an apparent correlation of students' attitudes towards learning complex concepts and the use of Web-based instruction to teach them, as demonstrated by the work of Summary and Summary (1998). Their analysis of freshmen and sophomore-level economics course students showed a significantly higher level of positive attitudes about learning economics when taught on-line compared with through traditional face-to-face in-class methods.

In a study of the attitudes of a group of 62 undergraduate students in a Human Physiology class, a comprehensive survey of students' attitudes to on-line learning was completed by Dewhurst, Macleod, and Norris (2000). The intent of the survey was to measure the effectiveness of on-line strategies based on computer-based learning (CBL). The researchers found statistically significant increases in the attitudes of students after the course was completed, citing the convenience and collaboration that on-line learning provided, and the opportunity to become less computer-phobic was also a benefit as well. What was also noteworthy about this study was that it found a statistically significant shift in attitudes of students after having completed the course using CBL-based applications and techniques. Despite the significant gain in positive attitudes for CBL-based learning strategies, students also mentioned that having a traditional in-class face-to-face session with instructors would also be useful. The point was made that a traditional course provided structure to their specific learning strategies as well.

When the perception of students with regard to on-line compared with traditional in-class face-to-face instruction was evaluated by Hughes and Hagie (2005), their research provided empirical validation that flexible time scheduling, freedom in expressing ideas and comments on-line including the ability to collaborate with others, and also the ability to stay focused on key concepts and insights relating to the class were all statistically significant findings in favour of on-line learning. This study also empirically proved that on-line learning made it more difficult to manage time in completing on-line tasks, and also the dearth of immediate feedback from instructors and peers. While collaboration was a major positive of having on-line teaching and learning tools, the students also stated they missed the opportunity to receive positive reinforcement in-person from other team members.

In additional studies, the effects of computer-assisted instruction (CAI) on both the attitudes of students to this specific teaching platform showed significant positive improvement (Goolkasian, 1989; Ware and Chastain, 1989). The effects of CAI on the overall increase in positive attitudes about computers has also been empirically tested (Spivey, 1983).

In terms of learning new languages, Web-based or enhanced learning have been empirically proven to lead to higher levels of positive attitudes in students who are studying language arts include listening comprehension exercises. By examining through research the integration of computer-delivered listening comprehension exercises into a university-level foreign language curriculum, it was found that students in the Web-based teaching course had a significantly higher attitude towards both the subject and Internet-based training (Despain, 1997). In addition, a study completed on students taking an introductory operations management course (Karuppan and Karuppan, 1999) showed that Web-based learning tools that provided tools for encouraging students to take more notes, study more often, and work towards retaining key concepts led to higher attitudinal rankings for the class and also a higher level of participation in class. The researchers had feared that having Web-based applications and tools would lead to truancy, when in fact the opposite occurred; students who used the Web-based tools arrived at class just as prepared, and in some cases, better prepared than students who had not used the on-line tools.

The effects of Web-based learning itself, leading to a more positive change in attitudes and performance, are also illustrated in the research completed by Felix (2001). He empirically concluded that students are more likely to be positively inclined to working with Web-based tools, and in general, find these tools very useful in preparing for class and examinations. Most significant, Felix found that the level of enjoyment students report increased over time as a result of using Web-based tools. In a semester-long exploratory study, Driver (2002) studied the effects of Web-centric learning on the student learning outcome of a MBA programme. He concluded that a Web-centric learning environment had a cumulative and lasting positive increase in course content involvement on the part of students. In addition, the use of collaborative tools also led to greater levels of social interaction and in general increased overall student attitude to the learning experience.

Attitude is one of the most important elements in student learning. It is found that a large part of the literature supports the positive effect of the on-line learning environment on the attitude of students towards the learning materials and environment.

For the Pedagogical Dimension, Felix (2001) suggests that students have reacted positively towards specifically using an on-line application in the physical classroom itself. The reasons cited for this is that students prefer to implement a new system of use on the basis of the system that they are accustomed to, rather than being expected to make a large paradigm shift at once. Another possible reason is that face-to-face students view on-line learning as a cost-cutting strategy, while on the other hand language learners may need more direct support from the teacher than those of other subject fields. Nevertheless, the positive experience when phasing in the Web in the traditional learning setup is encouraging.

Hughes and Hagie (2005) note that limited studies area available on the attitude cultivated by on-line learning, as it has only been a part of higher education systems for a relatively short time. Furthermore, many institutions are only beginning to phase in this paradigm, which may result in uncertainty during the learning process, also influencing the general attitude towards this new paradigm. The authors also note learning style in influencing the attitude of students to both the on-line and off-line learning environments. The more independent learner would for example prefer the on-line environment, while the learner who generally needs guidance and daily motivation tends to prefer the face-to-face class environment. The on-line environment has however implemented a positive aspect for learners with a more independent disposition that was not available in the traditional learning paradigm.

With respect to the Interface Design Dimension, Felix (2001) concentrates specifically on student attitudes cultivated by the interface design of a Web page upon student attitudes and achievement. Paradigms investigated in this light are based upon the subjective and emotional experiences of students during their interaction with the on-line environment during the learning process. Such experiences include the comfort and enjoyment level of using the Web-based environment, possible changes in these feelings with prolonged use, the perceived usefulness of Web-based materials, the comparison of on-line and off-line learning environments, preferred mode of delivery, etc. The study found a significant link between prolonged feelings of comfort and the perception of usefulness.

Goolkasian (1989) substantiates the generally positive attitude cultivated by and effective interface design. Goolkasian's focus is upon the implemented use of microcomputers in the laboratory of a psychological research facility. Both instructors and students report an overwhelmingly positive experience, with elements such as hands-on experience, the value of data analysis, and the generally exciting nature of Web-based instruction in the laboratory noted as particular points of interest. Additionally, the computerized laboratory has also been beneficial in encouraging independent research and demonstrations for more advanced courses.

In a laboratory environment, however, Spivey (1983) emphasizes that most students prefer a combination of off-line and on-line activities in order to experience the full benefits of the course material. The author warns that the Web environment cultivates the most positive attitudes in the majority of students when used in combination with off-line instruction, particularly for a practical field such as experimental sciences. While this technology therefore adds a valuable element of excitement, it is also important to relate it to the practical experimental environment in certain subject areas.

In the Evaluation Dimension, according to Spivey (1983), evaluation should be connected to the course goals. With the implementation of the on-line environment in the laboratory setup examined by the author, it was found that students perform better with the combination of on-line and off-line learning than only in the off-line setup. The author notes that the computerized environment is valuable in enhancing the positive experiences and attitudes of students in order to achieve more positive outcomes at the end of experimental psychology courses.

In contrast, some students in other studies have indicated a preference for the traditional classroom format. In one noteworthy study for example an assessment of comparative data was completed of students enrolled on both on-line and traditional face-to-face course formats, specifically taking a graduate-level Human Resources (HR) development course (Johnson, Aragon, Shaik, and Palma-Rivas, 2000). At a statistically significant level it was shown that the face-to-face group scored a statistically significantly higher attitudinal score on departmental support, instructor-driven support and also on student-to-instruction satisfaction.

Another line of research supported the "no significant phenomenon". Even when Web-based applications have been thoroughly produced with pre-recorded audio, related course pages indexed to the Internet, and detailed course outlines provided, the differences in student attitude ratings were not statistically different compared with those in traditional courses (LaRose, Gregg, and Eastin, 1998).

Student Satisfaction

The main goal of college courses is to produce student learning, but student satisfaction with the course is another important consideration. Relatively few studies have compared student satisfaction in Web-based and lecture courses and, as with the performance and attitude measures, the results are mixed.

Unfortunately, only very few studies show positive WBI effects on student satisfaction. One of the studies that show a positive impact of WBI applications and tools on student satisfaction is by Enockson (1997). This study empirically proved that on-line learning leads to higher satisfaction in students due to higher levels of responsiveness to learning requirements, more accurate alignment with their expectations and flexibility with regard to their schedules all lead to increased student satisfaction.

In another study, conducted by Liu (2005), a graduate-level educational research course was completed both in an on-line and traditional format. To alleviate instructor variability, the same instructor taught both courses. Liu found that the majority of students had a higher level of overall satisfaction with the course when it was taught on-line. Most students from the on-line class believed that they learned more than students from the traditional section.

In the light of the contemporary paradigms of information technology and the increased emphasis upon the necessity of computer literacy in the workplace, it is perhaps little wonder that students experience great satisfaction with the implementation of Web-based learning in the tertiary environment.

In the Pedagogical Dimension, according to a study by Enockson (1997), participants experienced a high degree of satisfaction with the implemented on-line environment, particularly as it related to enhancing their computer literacy and skills. Particularly, the technology, flexibility and individualization of these systems in terms of learning styles and time schedules were highly valued. Enockson emphasizes that the course materials investigated also resulted in a high level of student satisfaction. This indicates the importance of developing course materials that correlate well not only with the level of study, but also with materials in the off-line environment and with student expectations. Indeed, the quality of such materials also enhances the level of student confidence and satisfaction with course presenters. According to the author, students who experienced a high level of satisfaction with the course content at the same time experienced a high level of confidence in the lecturers presented the courses involved.

Liu (2005) addresses the correlation between student satisfaction and motivation. According to the author, students who experience a high level of satisfaction with the on-line materials also experience a higher level of motivation than those in the traditional classroom setup, which is vital in the eventual success of the outcomes. In addition, students reporting satisfaction with on-line content also experienced satisfaction with the effectiveness of their learning, believing that they learned more than students who were not exposed to on-line learning.

For the Interface Design Dimension, according to Enockson (1997), interface design issues also relate to the level of satisfaction that students experience with on-line material. The ease of use of email systems for example generally tend to relate to high satisfaction levels. According to the study, students find it extremely convenient to be able to contact instructors at any time according to their convenience and available time frame. This does away with the inconvenience of specific office hours or telephone availability. This satisfaction is however also related to the ability of the instructor to respond to email in a speedy fashion. In Enockson's study, for example, the instructor made an effort to consistently respond within 24 hours. Students also experienced the on-line system as particularly convenient, as physical barriers to communication were eliminated, and students were able to set their own hours for instruction and communication. The time and costs of commuting are also eliminated by the use of such a system. This is the basic advantage of a generally on-line system of instruction as opposed to the combination system.

Finally, with respect to the Evaluation Dimension, according to Enockson's findings, no significantly negative findings resulted from the study in question. Students experienced an overwhelmingly positive level of satisfaction with the on-line environment, of which the advantages far outweighed any potential disadvantages. It must be emphasized here that the quality of the on-line materials combined with the immediacy of response to communication and inquiries resulted in a high level of satisfaction. It should also be recognized that such satisfaction is often also correlative with the particular subject matter, learning styles and expectations of different students. Findings such as those by Enockson would therefore benefit from further and more comprehensive future study.

In contrast, some students in other studies have indicated a preference for the traditional classroom format. Research completed by Faux and Black-Hughes (2000) showed a higher level of satisfaction with and a preference for traditional classroom instruction. The researchers relied on a methodology of testing traditional in-class teaching, Internet-based only, and a hybrid approach. The statistically significant finding showed that students had a higher level of satisfaction with the traditional approach in that it provided for more interaction and a greater opportunity to listen to the key concepts and content of the course compared with viewing it on-line.

The research of Johnson, Aragon, Shaik, and Palma-Rivas (2000) also supports the contention that students are more satisfied when they have an opportunity to interact with peers and instructors as opposed to relying on a Web-based learning. The researchers had students enrolled into two versions (face-to-face and on-line) of a graduate-level HR course and rated their levels of satisfaction throughout the school year for their specific course platform. Students who had more peer interaction on a face-to-face level had higher satisfaction scores overall.

Satisfaction with courses seems to correlate more with the effectiveness and presence of the instructor and their ability to clearly and succinctly explain concepts in the course, in addition to providing valuable feedback to students. The research completed by Debourgh (1998) empirically showed that student satisfaction is more significantly influenced by the effectiveness and perceived quality of the instructor and less on the use of technology. This finding was also supported in the context of an introductory psychology course in which Maki et al. (2000) was able to show students having a statistically significant higher level of satisfaction with the lecture section. Likewise, the research of Sole and Lindquist (2001) found that students preferred learning in a live, traditional classroom format rather than in a Web-enhanced video course. Rivera, McAlister and Rice (2002) also supported the contention that students are more satisfied with the traditional and hybrid classes; and less so with the on-line course.

Some studies show no differences at all. Sandercock and Shaw (1999) found no significant differences in student evaluations of the course between a traditional and a WBI undergraduate course in Sports Science. A similar result of no significant differences in student evaluations of the course was also found by Ryan (2000) between lecture and on-line construction equipment and methods classes. Wang and Newlin (2000) found almost identical student ratings for a psychology course taught in both a traditional and Web-based format. Waschull (2001) also compared course ratings in an introductory psychology course conducted in two different formats: traditional classroom instruction and Web-based instruction. Results indicated students in the Web-based section expressed higher ratings, but the difference was not significant.

The research completed by Spooner, Jordan, Algozzine, and Spooner (1999) also showed no significant differences in satisfaction ratings as defined by students for traditional or distance learning courses, even when both course formats were taught by the same instructor. In addition, from an empirical standpoint, no differences were found in students' ratings of communication method, course, instructor or teaching style.

In the completion of a graduate-level special education course on both on-line (e-College) and also through traditional courses, students' ratings of teachers' performance were measured (Caywood and Duckett, 2003). The results of the research showed no significant difference in perceived teaching performance by instructional platform approach. In addition, another study (Skylar and colleagues, 2005) looked to correlate student satisfaction by looking at instructor course evaluations for a special education course offered in traditional classroom, on-line instruction using a WebCT-based approach and finally through a CRM-ROM based approach using multimedia CD-ROM. The results, like those of Caywood and Duckett showed no significant difference in student satisfaction as a result of analyzing both course evaluation and course surveys.

There are many advantages suggested for Web-based education. The teaching/learning process can take place at any time and any place. It also allows the teacher and learner to communicate over any distance. According to Schutte (1996), Web-based courses lead to a more positive attitude to both the learning process and the specific material of the course. From the accumulated research it is clear that the best predictor of learning is more dependent on the approach and effectiveness of the instructor first, and the instructors' ability to align their teaching strategies with the needs and perceptions of students (Wegner et al., 1999). What Web-based learning seems to be able to do, when done properly, is to enable teachers to teach in a more constructivist context that allows for more student-centred and real learning (Foley and Schuck, 1998; Shaw and Pieter, 2000) as well as provide opportunities for students to work independently and communicate anonymously (Ryan, 2000).

There is little doubt that education today is experiencing a revolution. Technology in the classroom is unavoidable and indeed is becoming a necessity. The only question is (and should be) how and to what degree to implement it. From the literature review above, for those studies that indicate positive outcomes in performance, attitude and satisfaction, it is clear that different situations and different students require different types of setup when including technology in the classroom.

In terms of the Pedagogical Dimension, student performance is generally higher when Web-based learning is included at least in combination with the off-line learning environment. The main reasons for this include the fact that students have the opportunity to experience direct contact with the practical applications of their study direction. Computer technology in the laboratory environment for example can help students become familiar with aspects of learning such as data analysis and research methodology.

Before replacing off-line learning with an on-line environment, student attitudes and learning styles should be thoroughly investigated. An emphasis should also be placed upon gradually familiarizing students with computer technology in order to eliminate uncertainty and fear. Student attitude and satisfaction in terms of the pedagogical dimension are also shown to be more positive with the inclusion of the on-line environment than off-line.

In terms of Interface Design, students' performance, attitude and satisfaction levels are all overwhelmingly positive. The literature shows that students particularly appreciate an interface by which the instructor is readily available. Emphasis should be placed upon the way in which the instructor handles interaction and communication in order to ensure the success of such an interface. Furthermore, an initial attitude of fear and/or resentment may be experienced when the interface is not designed in an effective and user-friendly manner.

Evaluation relates both to the assessment of students during and after the course, and to the evaluation of teachers and the materials presented in the on-line environment. In terms of student evaluation, it is reported that students perform well with test and assignment materials presented in the on-line environment. Indeed, some perform better with the on-line setup than in the face-to-face classroom setup. In terms of attitude and satisfaction, instructors also show a positive trend towards students who work with on-line material.

Students' evaluation of on-line course material has been shown to be overwhelmingly positive when such material is created in correlation with the course goals and outcomes, as well as with the quality of instruction and response. Students show an appreciation for the fact that inconveniences such as commuting and physical barriers are eliminated from the communication and learning process. Interaction is also enhanced by the on-line environment, in that this environment is conducive to a greater level of confidence.

In general, it appears that students are shown to benefit from including Web-based instruction either in combination with face-to-face instruction or in an environment that is entirely on-line. It is likely that different approaches and combinations will be necessary for different subject areas and student needs.

But there are also some very real drawbacks along with the potential advantages of Web-based learning. Probably the most important drawback is putting students into the position of having to move up a technology learning curve, especially for those students with little prior knowledge of software (Robinson et al., 1998; Wegner et al., 1999) or associated hardware requirements for learning systems (Foley and Schuck, 1998; Teeter, 1997; Wegner et al., 1999). The fact that systems go down periodically either due to a software bug or for routine maintenance can be unpredictable (Foley and Schuck, 1998) and often lead to high levels of frustration with students, including resentment and even anger. Both these significant barriers and the fact that many students are not motivated to become highly computer literate lead to significant barriers in Web-based learning adoption (Robinson et al., 1998). The downside of Web-based learning also includes both student isolation and passivity (Wegner et al., 1999), the perception of time being much shorter, therefore tasks more urgently needing to be done make students feel like they are working all the time on an on-line course (Schutte, 1996) are also detriments to Web-based learning growth. All of these limitations are evident in research that says the best distance learners are those who are mature in age, have exceptional time management skills, and have chosen on-line learning for its flexibility (Hiltz, 1990; Picciano, 1998). Still other researchers have stated that given the nature of on-line learning it is difficult to evaluate its true value through the existing assessment methods which are available (Ryan, 2000).

One of the more interesting researchers and authors with contrasting views on Web-based education is Clark (1983) who stated that the Web no more enriches the educational experience than a truck enriches food on the way to a grocery store. In much of the research in this review, no significant differences were found. Kennedy (2000) has theorized that the most mature, motivated, and talented at time management students enroll in on-line courses, and would succeed regardless of the format the class is taught in.

Robinson and Levy (1996) found additional support for Clark (1983), finding that television viewers who watched the news were just as informed as those who learned of events through other media and channels. Contrary to this finding is the research completed by Tewksbury and Althaus (2000), illustrating that the media carrying the information does in fact make a significant difference to the acquisition and retention of knowledge.

Inconsistent as those findings may seem, the results are also far from being conclusive, since two key drawbacks were found in the current research of the effect of

Web-based, or enhanced learning on students' learning outcome. First and most critical from a methodology standpoint, the studies vary in their use of randomly selected participants, use of sound methodology, and as a result at times lack statistical and reliable validity. Second, the majority of research studies are oriented to just a single course rather than the longer-term implications of Web-enhanced learning on the entire college learning experience. Clearly the result of learning strategies in one course cannot be extrapolated to all. This is because the dominant variables of instructor competence and strategy must be normalized over an entire academic career to see the true effects of Web-based, or enhanced learning.

Web-based, or enhanced learning has become increasingly important and attractive, but more research needs to be done to further explore its effect on students' learning outcome.

CHAPTER 3

METHODOLGY

This chapter covers the overall design of the study. It explores the methodological issues involved, including the populations to be involved and methods of assessment. Section 3.1 explores the research philosophy. The design of the study will be described in Section 3.2 and the characteristics of the participants in Section 3.3. Section 3.4 provides the procedure of the study. Section 3.5 looks at the two instruction methods that were used in the study. A whole gallery of Java applets is included in this section. Section 3.6 focuses on the instrumentation used to gather demographic information, student performance, student attitude and also student satisfaction. This section also includes a description of the instruments and an evaluation of their reliability and validity. Section 3.7 looks at the research ethics. Section 3.8 includes an evaluation of the validity of this study. The data-analytic techniques used in the data analysis are specified in Section 3.9.

This study aims to develop a collection of Java applets to help students learn some statistics concepts more easily than before.

The independent variable in this study was the method of instruction, a variable with two categories: Java applet-based teaching method and traditional classroom teaching method. The dependent variable was the scores on the post-test.

3.1 RESEARCH PHILOSOPHY

The design of any research study begins with the selection of a paradigm. In the field of educational research, positivism and interpretivism have been the two main contexts within which to conduct such research, and these have been competing contexts. Hayes (2000) defines positivism as "an approach to research which insists that only observable, measurable data should be the subjects of study" (p.374) and interpretivism as "an approach to research which emphasises the human interpretation of meanings and implications; introduced as a challenge to hard-line positivism" (p.366).

Positivism focuses on generalisability and casual explanation. Positivism accepts only that which has been verified by hypothesis formation and testing:- positivists speak of proof. Positivists tend to take the view that the only valid data is concrete data that exists in a physical reality; positivists will not consider any data relevant unless it can be measured in a physical sense. Therefore, when conducting educational research, positivists want hard data. They will only consider data based upon a person's perceptions to be relevant if these perceptions can be observed in physical action. Interpretivism, on the other hand, focuses on relativism and understanding:- interpretivists speak of interpretations. Interpretivists look at valid data as that which comes from the perceptions of the people being studied. Because of this, the interpretivist approach has often been called the anti-positivist approach.

This is an evaluation study which proposes to explore the impact of the use of Web-based applets on statistics education on student performance, attitude and satisfaction. This research study falls within the positivist paradigm. In adopting the positivist paradigm, this research is aiming to establish, explain, predict casual links between key variables. Quantitative research methods are predominantly used in the positivist approach (Mertens, 2005). "In quantitative studies," Creswell (1994) notes "one uses theory deductively and places it toward the beginning of the plan for a study. The objective is to test or verify theory. One thus begins the study advancing a theory, collects data to test it, and reflects on whether the theory was confirmed or disconfirmed by the results in the study. The theory becomes a framework for the entire study, an organizing model for the research questions or hypotheses for the data collection procedure" (pp.87-88). The primary/common quantitative data collection methods include surveys, experiments, questionnaires and structured observation. The data gathered will then be analysed using appropriate statistical techniques.

Quantitative research methodology is the main methodology of this research which uses tests (pre-test and post-test) and questionnaires (demographic survey, pre-/post-instruction attitudinal survey, and also a course evaluation form) to collect data from participants, and then analyses with statistical procedures (such as descriptive data analyses, t-tests, F-tests, and bivariate tests), in order to determine whether the predictive generalizations of the research hypotheses hold true.

There are, however, limitations associated with quantitative research; one is the requirement of large samples (sometimes several thousands). This is because quantitative research depends on large sample sizes to lead to conclusions that can be generalized. The sample population for the present study was relatively small which may undermine the accuracy, validity, and generalisability of the study. Based on the well-known Central Limit Theorem, a sample size of 30, which the present study had (37 for experimental and 38 for control), is usually large enough for statistical tests and the generalization related to those tests provided that the sample is normally distributed for the given variables.

3.2 RESEARCH DESIGN

This study utilized a quasi-experimental pre-test/post-test nonequivalent control-group design that was a suitable alternative to an experimental design due to the random assignment of participants to experimental and control groups not being possible (Cook and Campbell, 1979; Gall, Borg, and Gall, 1996). Rather than randomly assigning students to groups as they would be in an experimental design, intact classes of students were being used. The students from one class were assigned to the experimental group (Java applet class) and the students from the other class were assigned to the control group (traditional class). Both intact groups took a pre-test and a post-test. The design of this study could be diagrammed as follows:

Experimental group:	O_1	X	O_2
	------	------	------
Control group:	O_1		O_2

("O" means "observation", "X" means "intervention", with the passage of time being represented by the movement from left to right.)

3.3 RESEARCH PARTICIPANTS

The sample consisted of a group of second year full-time undergraduate Computer Studies students at the School of Public Administration (ESAP) at the Macau Polytechnic Institute (MPI), Macau. The random assignment of participants to control and experimental groups was not feasible. Participants in this study were enrolled in MMAT270 (Statistics). MMAT270 is a required course for all undergraduate students and is the first and introductory course in statistics and has no perquisites or requirements for any statistical skills.

Three sections of this course were taught. For the purpose of this study, two intact sections were randomly selected and assigned to two groups, such that 37 students appeared in the Java applet class (experimental group) and 38 appeared in the traditional class (control group). A total of 75 students participated in this study. Of the 37 experimental group participants, all were Chinese, 24 men and 13 women, and the age range and mean were 18 to 22, 19.86, respectively. And of the 38 control group participants, all were Chinese, 27 men and 11 women, and the age range and mean were 18 to 23, 19.95, respectively.

To collect accurate information, enhance cooperation, and increase the number of volunteers, students were assured that their identity and responses would be kept confidential.

3.4 PROCEDURE

This study was conducted during the fall semester of the 2006-07 school year. On the first day of class, two of the three intact sections were randomly assigned to two groups, one group was taught by the Java applets-based teaching method and the other group was taught by the traditional classroom teaching method. The evaluation began with the distribution of a letter of informed consent (see Appendix E – Letter of Informed Consent). This letter described the purpose of conducting the evaluation, authorization for the study, and assured respondents of anonymity and confidentiality of information supplied by the respondents.

Next, the traditional class was given a demographic survey (see Appendix F), while the Java applet class was given a demographic survey (see Appendix F) as well as an attitudinal survey (see Appendix G).

Following the surveys, a pre-test (see Appendix J) was administered to both groups of students prior to commencing the lesson. The pre-test was helpful in assessing students' baseline knowledge of course content and also in determining the initial equivalency of both groups of students. At the end of the course, both groups of students completed the final examination (see Appendix K) as a post-test measure. The post-test was useful in testing whether the applet class had increased students' understanding of the topic.

Additionally, the Java applet class was given another attitudinal survey (see Appendix H). The traditional class was not given the attitudinal survey because it was not applicable.

Both groups of students completed the course evaluation form (see Appendix I) at the conclusion of the course. This form was designed to obtain an insight into the students' perceptions of the overall quality of the instruction and the course.

In order to maximize comparability, the same text, syllabus, assignments and examinations were used in both groups. The same instructor was responsible for teaching all of the sections involved and both groups met the instructor twice a week over a 15-week semester. Each class section would last one and a half hours. Students from both groups took identical examinations at the same time and location. In addition, student names were obscured during the grading process in order to minimize testing bias.

3.5 INSTRUCTIONAL METHOD

3.5.1 Java Applets-based Teaching Method

The Java applet-based class additionally incorporates Java applets into the traditional lecture format, i.e., the instructor will use Java applets to supplement the lecture with dynamic illustrations of relationships between concepts. In order to promote a deeper understanding of the key concepts and to stimulate reflective learning, each applet is accompanied by:

- an overview of the key underlying statistical concepts
- step-by-step instructions for using the applet
- a dynamic and interactive illustration
- a follow-up exercise that could be used as a class demonstration or a homework assignment

The applet-based instruction is intended to create a student-centred learning environment. The aim is to improve student learning. Knowledge exists inside the students' mind, and is actively constructed and created by the students themselves. New understanding is built upon students' prior knowledge and previous experiences. Learning is highly interactive and collaborative. The students compete with their own previous experience, not against their peers. Under this approach, the students are in control of their own learning and they are active constructors of knowledge; teacher acts as facilitators for knowledge acquisition and enhanced understanding. The students are actively involved in hands-on activities, applet-based activities, and collaborative learning groups. The key emphases are on promoting active participation, encouraging exploration, facilitating knowledge building, strengthening students' visual literacy skills, engaging in authentic inquiry, exposing students' misconceptions and learning difficulties, fostering student collaboration, promoting a deeper understanding of abstract or complex statistical concepts, and stimulating higher-ordered thinking.

3.5.1.1 *Gallery of Java Applets*

In order to create an interactive learning environment, a collection of Java applets was constructed based on three interface design principles:

- **Visual**: Stressing the visual aspects of how statistics makes abstract concepts more easily understood and more quickly applied.
- **Active**: The greater the activity of students, the higher the level of learning. Being actively involved with the concepts, as is possible with Java applets, leads to improved learning.
- **Engaging**: To be attractive and intuitive in design make the complex concepts of statistics appear to be more fun than drudgery.

The bottom line is that for students to gain the most value from statistics they need to "See Statistics, Do Statistics, and Enjoy Statistics!"

Visual

The extensive graphical capabilities of the Internet allows for ease in placing, publishing, modifying and saving complex graphics from virtually any website or location accessible through the HTTP protocol. This is a technological foundation for completely modifying the dynamics of how classrooms manage the economics of learning. Traditional classrooms rely on the significant costs of instructors producing classroom lectures, the production of graphs, charts, and images. In fact the Internet makes the entire production and publishing process much easier and much less time consuming and costly to complete. As the Internet has proven, images and graphics in general are very effective educational and learning tools. The many applications of the Web, and with it, the entire growth of WBT shows that the most abstract statistical concepts can be much more effectively taught using a combination of traditional instruction and Java applets.

Active

Active learning leads to greater retention of knowledge, specifically in the areas of more abstract and conceptual subjects, including statistics. Numerous learning studies support this contention, as do the many in-class experiences obtained during this study. The resulting research on passive learning not yielding any significant long-term learning is supported in landmark research relating entropy on learning cycles to passivity in learning response (Prince and Felder, 2006). The passive activities that collectively comprise lean back learning (Little, 2005) include passively taking in the content of videotapes and lectures, or simply reading through the content of books and not having to exercise the discipline to apply the concepts covered. Clearly lean back learning only asks the minimum of students in terms of learning, which equates to the development of just enough learning to get by and pass a course compared with internalizing concepts and truly understanding them. This approach will correspond to surface learning approach (Marton and Saljo, 1976a, 1976b) in which learning is essentially concerned with memorizing information.

In contrast to the lean back learning approach which is prevalent in many of the approaches to teaching today, interactive learning tools including interactive graphics actively involve students in learning, applying, and continually developing skill sets that are complimentary to the use and retention of knowledge. These series of approaches are collectively called lean forward learning strategies (Little, 2005) and include the students in each step of the learning process. The use of graphics to simplify complex concepts and create a continual sense of accomplishment on the part of students is actively promoted as well. Lean forward learning is also a critical step in many of the technology-based approaches to making Java applet-based technology a critical foundation for teaching both mathematics and statistics courses. The added element of students being able to quickly learn and control their pace of study is also a major benefit of using technologies for lean forward learning. This will be closer to a deep learning approach (Marton and Saljo, 1976a, 1976b) in which students engage in critical thinking. This means that students do not just reproduce knowledge, they explore and discover statistical concepts on their own.

It is critical for students to have the freedom of deciding their own pace, creating their own learning strategies in essence for the more difficult concepts being covered. This is at the heart of what makes interactive learning a lean forward strategy as it promotes active and self-measured progress over time. Interactive graphics in general and Java applets specifically save students the many steps of completing problems by hand and show what the result of the analysis will be. From this "beginning with the end in mind" approach to learning it is clear that interactive learning shows why the many equations and their proper sequence of solutions is critical for achieving both a solid foundation for statistical concepts and also a strong sense of how to solve the intricacies of calculations and most importantly, why they matter. This in and of itself is a major victory in the teaching of students who often wonder about the relevance of drudgery over analytical insights.

<u>Engaging</u>

Any aspect of learning where the student is in control is fun, preferable to lectures or instructors, enthusiastic to teach, who often speed through materials and equations in the process. An instructors' level of passion for a subject may be both invigorating and challenging to stay up with, yet the bottom line is that passion for a subject must translate into a sense of wonder and fun if lasting learning is to take place. When this happens any subject becomes fascinating, yet at the same time intimidating.

What instructors need to do is support and strengthen their own passion for teaching statistics with interactive graphics and tools for making this subject, which for decades has been accused of being arcane and dry for decades, fun! Statistics as a subject has a reputation for being dry and difficult to learn, yet with the combination of allowing students their own pace in creating their own examples within the applets, statistics can be fun. In the context of the applets being discussed, the main page of the applications provides the necessary tools for customizing the interface by students. In keeping with the objective of allowing students to have easier navigation and support for key concepts, a collection of Java applets has been developed. A key objective in creating these applets is supporting and creating a clear vision of underlying key statistical routines and concepts. The design of the applets is specifically focused on making them easily navigable to accomplish the learning objective of having students internalize the key concepts.

The gallery was made up of 15 Java applets and was easily accessible at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/statisticsIndex.html

(i) Sample Standard Deviation Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/StandardDeviation/SD.html

Overview

A commonly used measure of dispersion is the standard deviation (often abbreviated as s.d.), which is simply the square root of the variance. The variance of a data set is calculated by taking the average of the squared differences between each value and the mean value.

Because the differences have been squared, so the units of variance are no longer the same as the units of the original data. However, the standard deviation is the square root of the variance and will be measured in the same units as the original data.

The computation and notation for standard deviation and variance depend on whether we are dealing with the entire population or a sample set. By convention, we use Greek characters to denote population parameters and Arabic characters to denote sample statistics.

The notations for standard deviation and variance are as follows:

σ = population standard deviation

σ^2 = population variance

s = sample standard deviation

s^2 = sample variance

The definitional formula for the population variance is given as:

$$\sigma^2 = \frac{\sum_{i=1}^{N}(X_i - \mu)^2}{N}$$

The population standard deviation (σ) is the square root of this value.

The sample variance is calculated in a similar manner, using the appropriate notation for sample mean and number of observations. However, while the sample mean $(\bar{x})$ is an unbiased estimator of the population mean (μ), the same logic does not hold true for the sample variance if it is calculated in the same manner as the population variance. If one took all possible samples of size *n* and calculated the sample variance of each combination using *n* as the denominator and average the results, the value tends to underestimate the true value of the population variance. This underestimation can be corrected by using $(n-1)$ in the denominator instead of just *n*, in which case the sample variance (s^2) becomes an unbiased estimator of the population variance (σ^2).

The definitional formula for the sample variance becomes:

$$s^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}$$

The sample standard deviation (s) is the square root of this value.

The standard deviation is small when data are clustering closely around the mean and large when data are widely spread apart.

The two most commonly used measures of dispersion are standard deviation and variance. Additional measures include the range and mean deviation.

Level of Abstraction of Underlying Concept

Very high. Students are familiar with the concept of measure of central tendency (e.g., mean, median and mode) but they get quite confused with the concept of measure of dispersion (e.g., standard deviation and variance). Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of dispersion. In designing this applet, data and diagrams were generated automatically, but step-by-step, to allow for interactive exploration of the underlying concept. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate standard deviation.

Objective

This applet is designed to demonstrate the basic properties of the standard deviation. Statistics describing the spread or variability of the data are important to know because they tell us how well the descriptions of the centre (the mean and median) represent all the data values, and they are useful when comparing data.

For demonstration purpose, consider the following two data sets on the ages of all workers working for each of the two small companies:

Company A:	47	33	35	46	36	49	34
Company B:	70	33	18	52	27		

Using a calculator, we can verify that the mean age of workers of each of these two companies is the same, 40 years. If we do not know the ages of individual workers for these two companies and are told only that the mean age of the workers in both companies is the same, we may deduce that the workers of these two companies have a similar age distribution. But, in fact, the variation in the workers' ages in each of these two companies is very different.

From the applet, you can observe that the observations in the data set for Company B are more spread out from the mean than those in the data set for Company A.

The deviation from the mean for a particular observation is found by subtracting the mean from the observation. The deviations from the mean for the seven observations for Company A are

Age	47	33	35	46	36	49	34
Deviations	+7	−7	−5	+6	−4	+9	−6

A negative deviation indicates that the score is below the mean, and a positive deviation indicates that the score is above the mean. Notice that the deviations sum to zero (because the mean is the balance point of the data, the negative deviations cancel out with the positive deviations).

The sum of the squared deviations is:

$$SS_A = (+7)^2 + (-7)^2 + (-5)^2 + (+6)^2 + (-4)^2 + (+9)^2 + (-6)^2 = 292$$

Thus the standard deviation is

$$s_A = \sqrt{\frac{292}{6}} = 6.98$$

For Company B, the deviations from the mean are

Age	70	33	18	52	27
Deviations	+30	−7	−22	+12	−13

Notice that these deviations from the mean are much larger than those for Company A, indicating that the data are much more spread out. Again, notice that the deviations sum to zero.

The sum of the squared deviations is

$$SS_B = (+30)^2 + (-7)^2 + (-22)^2 + (+12)^2 + (-13)^2 = 1746$$

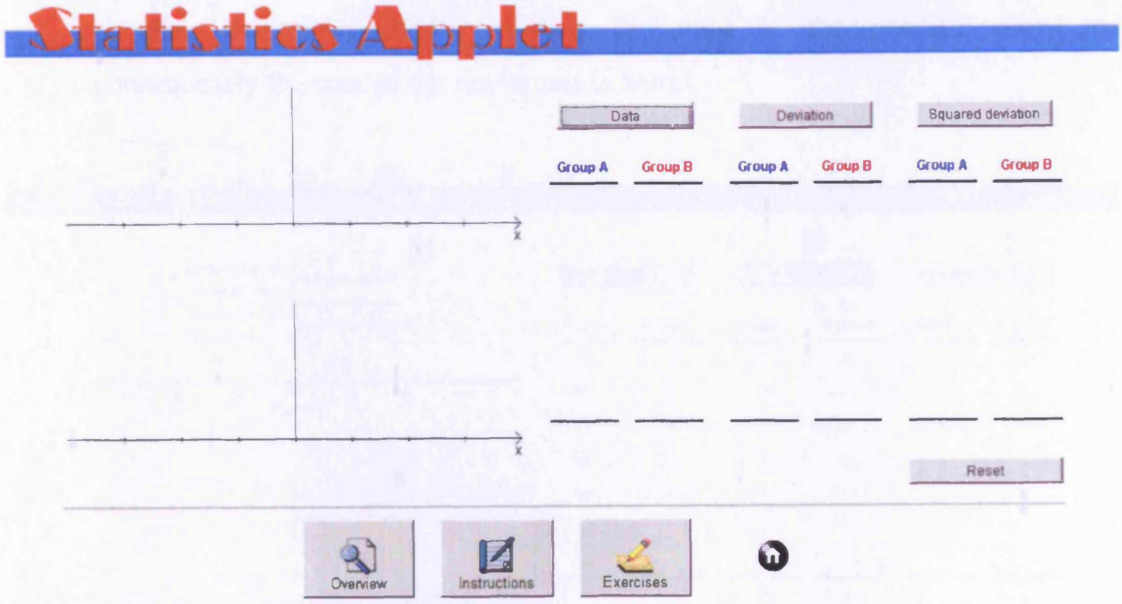
Thus the standard deviation is

$$s_A = \sqrt{\frac{1746}{4}} = 20.89$$

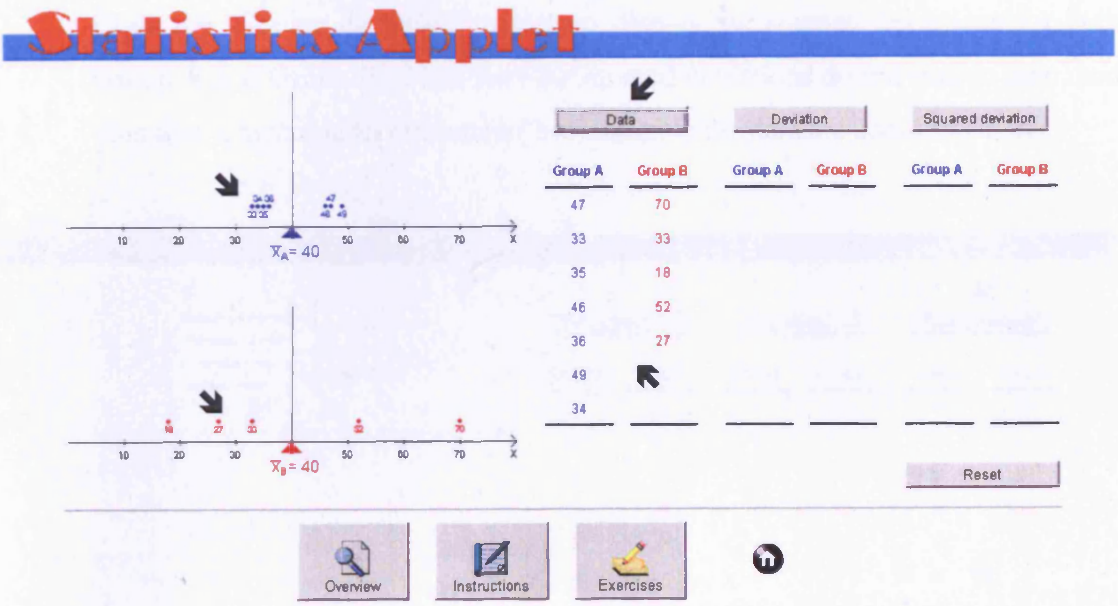
which is larger than the standard deviation of the age for Company A.

Instructions

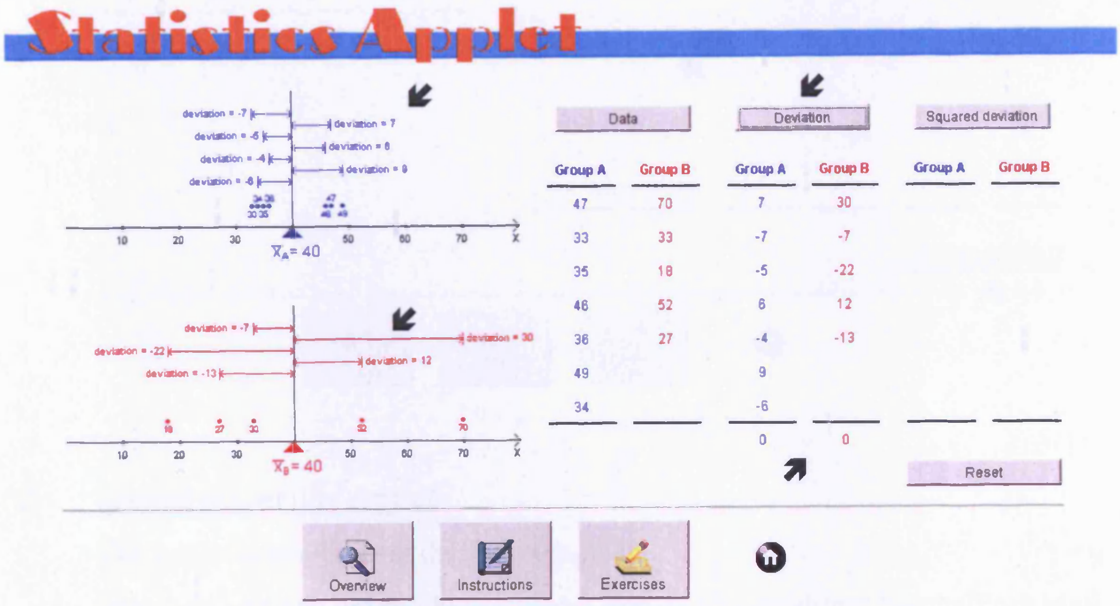
When the applet is loaded, the opening screen will appear as:



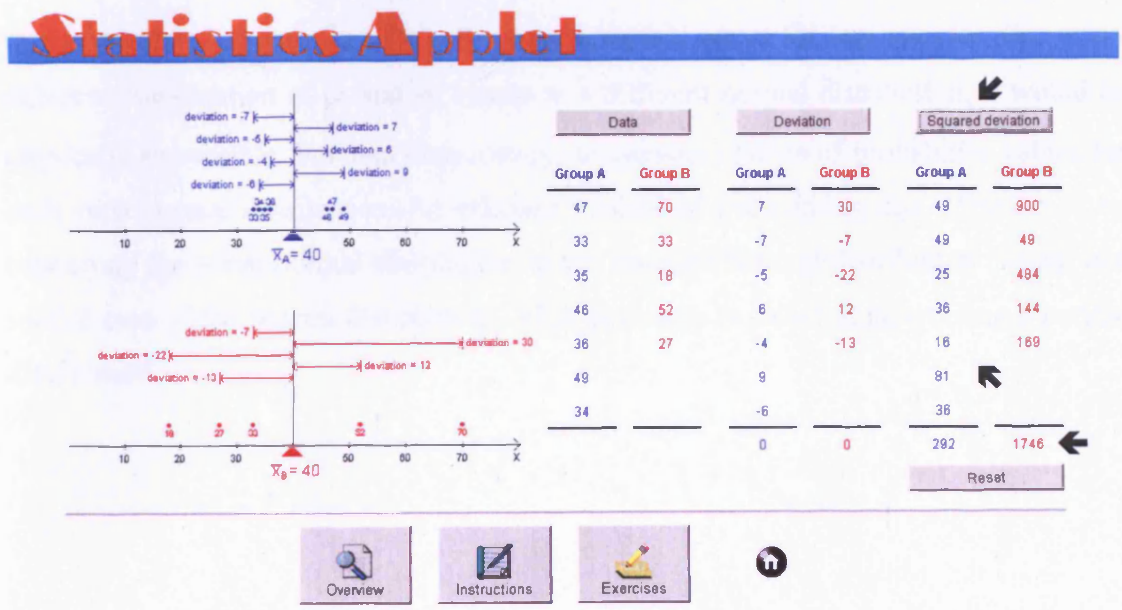
1. Click the "Data" button to display the data points and the sample means for both Group A and Group B.



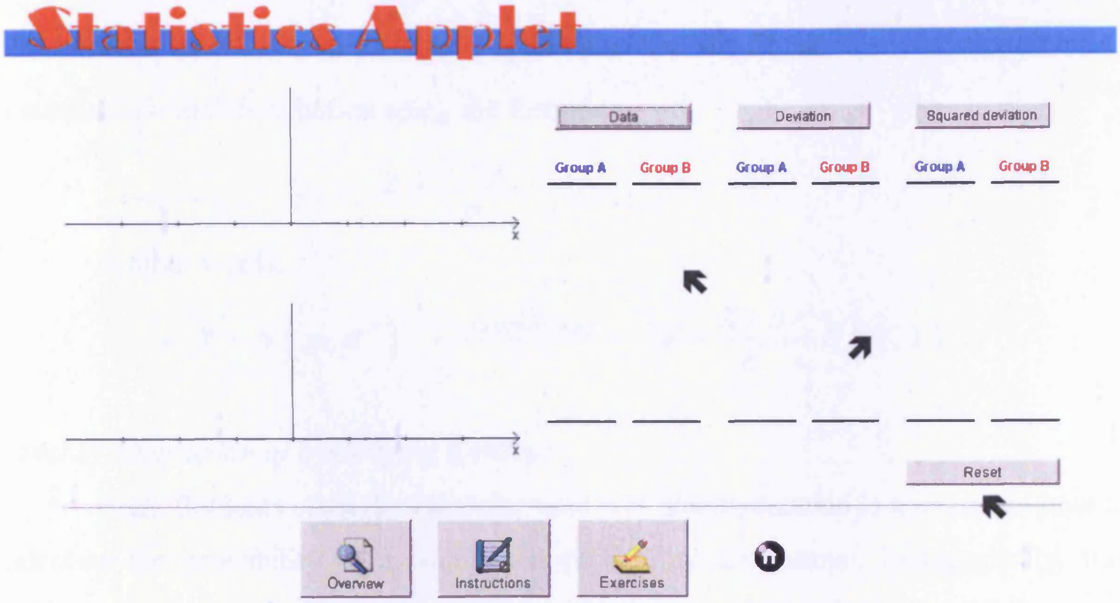
2. Click the "Deviation" button to display the deviations from the mean for both Group A and Group B. [Note that because the mean is the balance point of the data, some deviations are negative and some are positive, and the total of the negative deviations exactly cancels the total of the positive ones, and consequently the sum of the deviations is zero.]



3. Click the "Square deviation" button to display the squared deviations for both Group A and Group B. [Note that the squared deviations do not sum to zero, and thus give a meaningful measure of how variable the data are about the mean.]



4. Press the "Reset" button to start over again.



(ii) Normal Probability Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/NormalProb/NormalProb.html

Overview

The normal distribution (also called the Gaussian distribution) is the most important and widely used distribution in statistics. The mean μ and the standard deviation σ are the two parameters of the normal distribution. Given the values of these two parameters, we can find the area under a normal curve for any interval. But every different combination of μ and σ results in a different normal distribution; it would be physically impossible, but also unnecessary, to construct tables of probability values for each such normal distribution. An efficient method of overcoming this difficulty is by converting the given normal distribution to the standard Normal distribution (which is a special case of the normal distribution). This procedure is called 'standardising a normal distribution'.

A normal distribution having $\mu = 0$ and $\sigma^2 = 1$ is called a standard normal distribution. The random variable associated with this distribution is usually denoted by *Z*. The notation we will use is $Z \sim N(0\ ,\ 1)$. Any normal distribution can be transformed to a standard normal distribution using the formula:

$$Z = \frac{X - \mu}{\sigma}$$

In other words,

$$X \sim N(\mu, \sigma^2) \xrightarrow{\text{standardising}} Z = \frac{X - \mu}{\sigma} \sim N(0\ ,\ 1)$$

Level of Abstraction of Underlying Concept

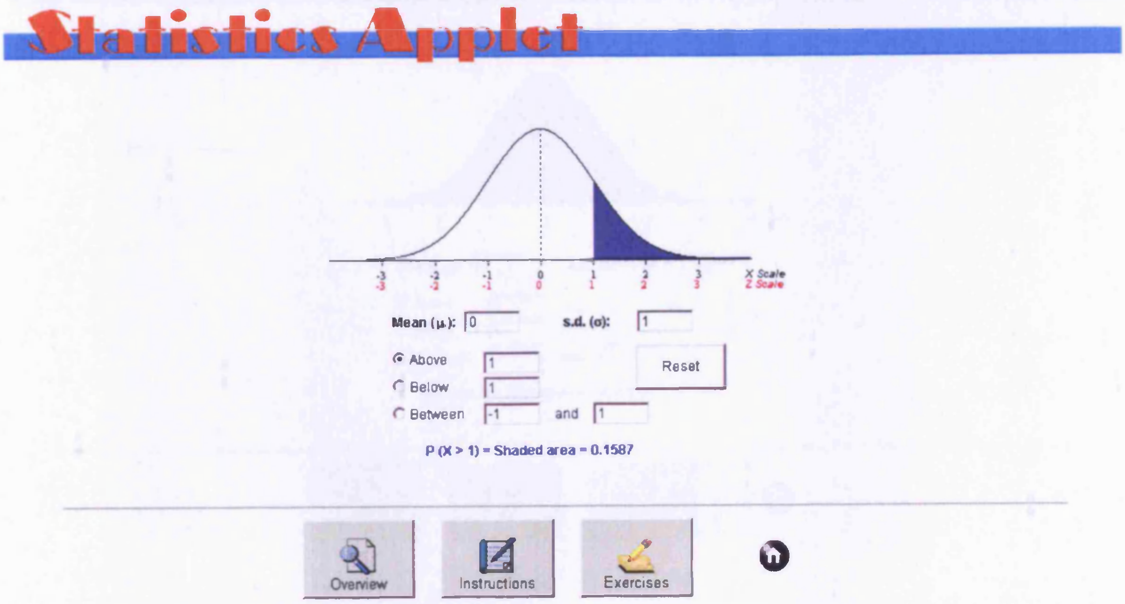
High. Students often do not understand why standardization is needed and how to calculate the probability of a continuous probability distribution. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of calculating normal probabilities. In designing this applet, radio buttons and value boxes were deployed to create a dynamic and interactive learning environment. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate normal probabilities.

Objective

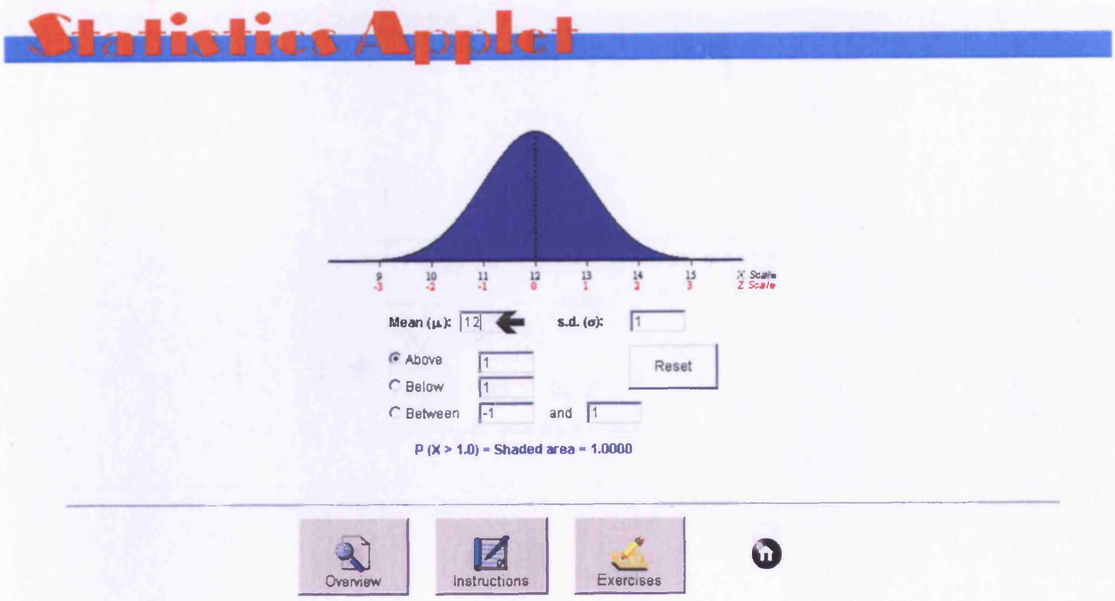
This applet is designed to calculate normal probabilities which also show the corresponding area under the normal curve with any lower and upper bounds.

Instructions

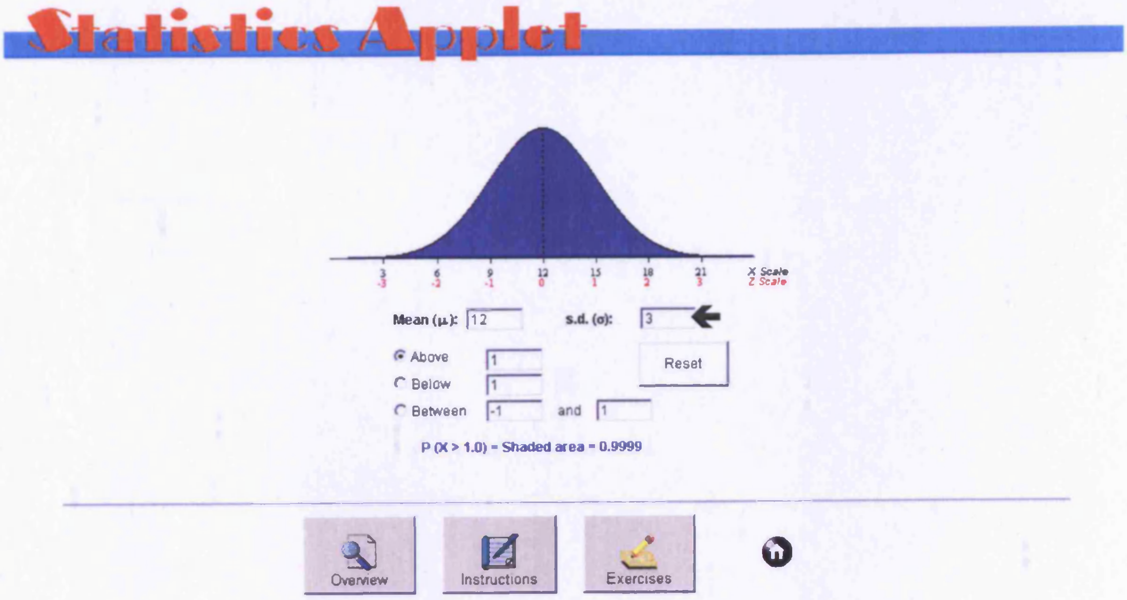
When the applet is loaded, the opening screen will appear as:



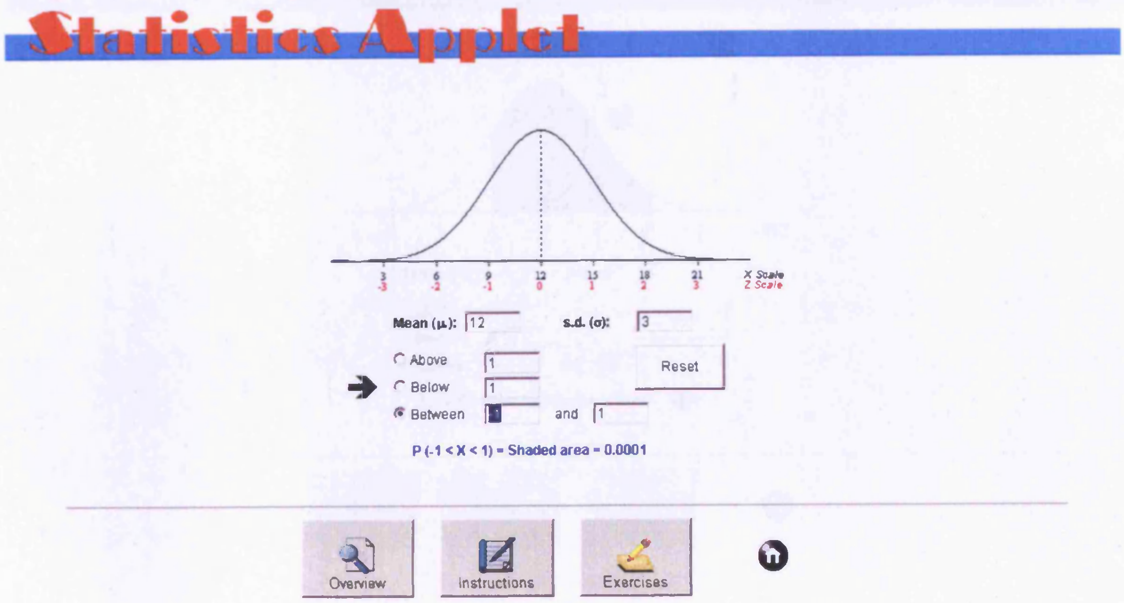
1. Input a value for the normal distribution mean (μ).



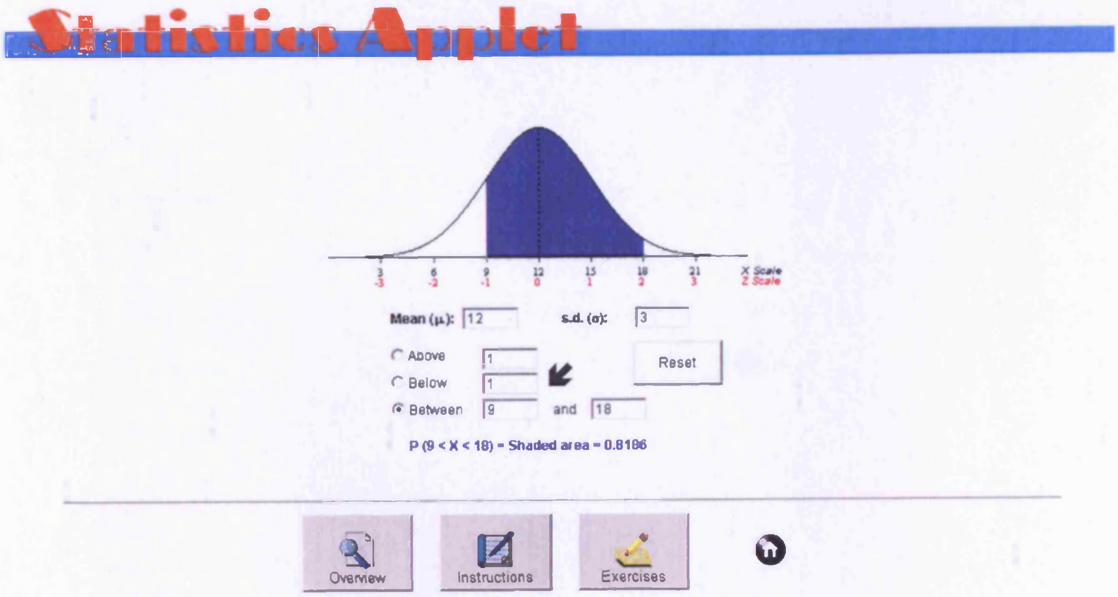
2. Input a value for the normal distribution standard deviation (σ).



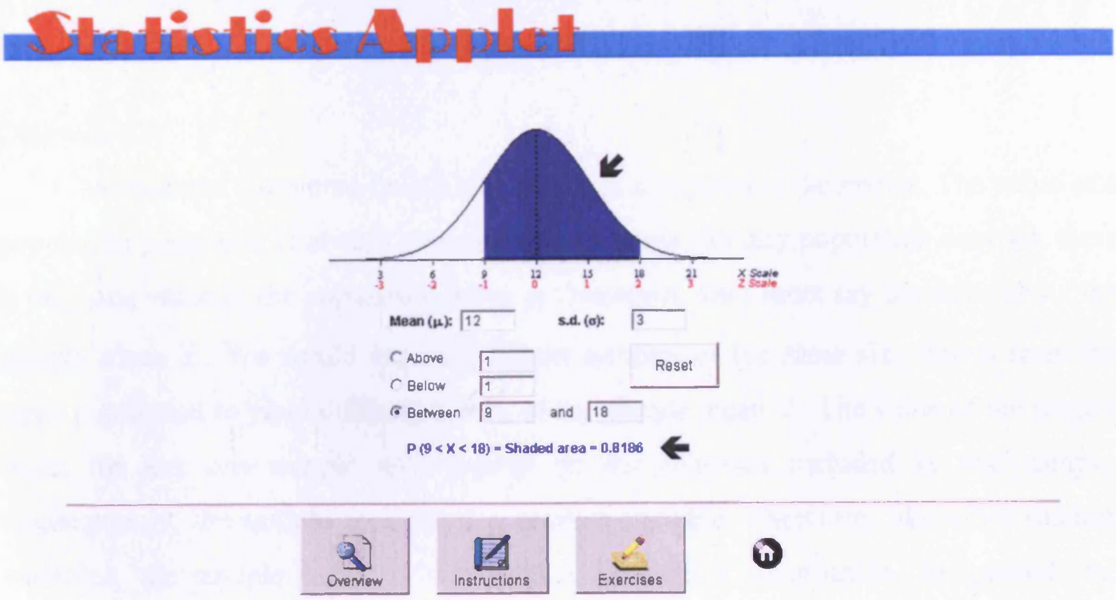
3. Depending on the type of the normal probability question, select the appropriate radio button: "Above", "Below", or "Between".



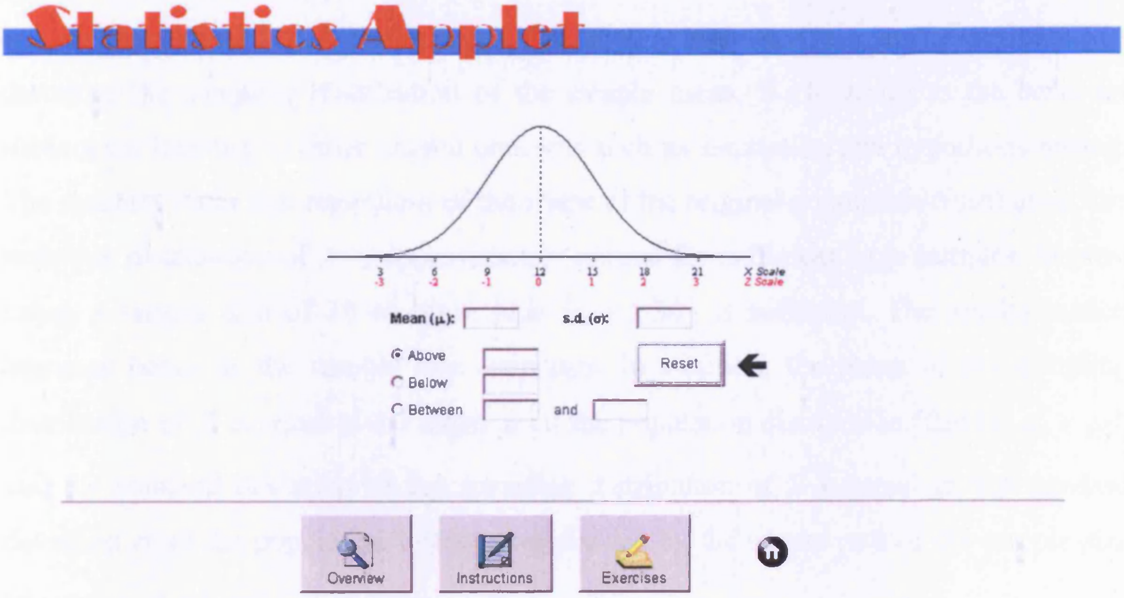
4. Input a value for the cutoff point.



5. The probability, the area under the normal distribution, will be computed.



6. Press the "Reset" button to start over again.



(iii) Central Limit Theorem Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/CLT/CLT.html

Overview

A measure computed from a population is a population parameter. The value of a population parameter is always constant. For example, for any population data set, there is only one value of the population mean μ. However, we cannot say the same about the sample mean $\bar{x}$. We would expect different samples of the same size drawn from the same population to yield different values of the sample mean $\bar{x}$. The value of the sample mean for any one sample will depend on the elements included in that sample. Consequently, the sample mean $\bar{x}$ is a random variable. Therefore, like other random variables, the sample mean $\bar{x}$ possesses a probability distribution. In general, the probability distribution of a sample statistic is called its sampling distribution. Specifically, the probability distribution of $\bar{x}$ is called the sampling distribution of $\bar{x}$. It lists the various values that $\bar{x}$ can assume and the probability for each value of $\bar{x}$.

The mean and standard deviation calculated for the sampling distribution of $\bar{x}$ are called the mean and standard deviation of $\bar{x}$. Actually, the mean of $\bar{x}$ (denoted by $\mu_{\bar{x}}$) is the mean of all sample means and the standard deviation of $\bar{x}$ (denoted by $\sigma_{\bar{x}}$) is the standard deviation of the means of all samples. The standard deviation of $\bar{x}$ is also called the standard error of $\bar{x}$.

The Central Limit Theorem (CLT) is a very important theorem in statistics that describes the sampling distribution of the sample mean, $\bar{x}$. It serves as the basis for subsequent learning in other crucial concepts such as estimation and hypothesis testing. The theorem states that regardless of the shape of the original population distribution, the sampling distribution of $\bar{x}$ is approximately normal for sufficient large samples. In most cases, a sample size of 30 or more [that is, $n \geq 30$] is sufficient. The approximation becomes better as the sample size increases. In addition, the mean of the sampling distribution of $\bar{x}$ is equal to the mean μ of the population distribution [that is, $\mu_{\bar{x}} = \mu$], and the standard deviation of the sampling distribution of $\bar{x}$ is equal to the standard deviation σ of the population distribution divided by the square root of the sample size [that is, $\sigma_{\bar{x}} = \sigma/\sqrt{n}$].

If the original population is normal, the sampling distribution of $\bar{x}$ will be normal for any sample size. If the original population is non-normal, the sampling distribution of $\bar{x}$ will become approximately normal for when n is large. The approximation becomes more accurate as the sample size becomes larger. Generally speaking, the more the population deviates from a normal distribution, the larger the sample size must be in order to get a reasonable approximation. In most cases, a sample size of 30 or more is adequate.

Level of Abstraction of Underlying Concept

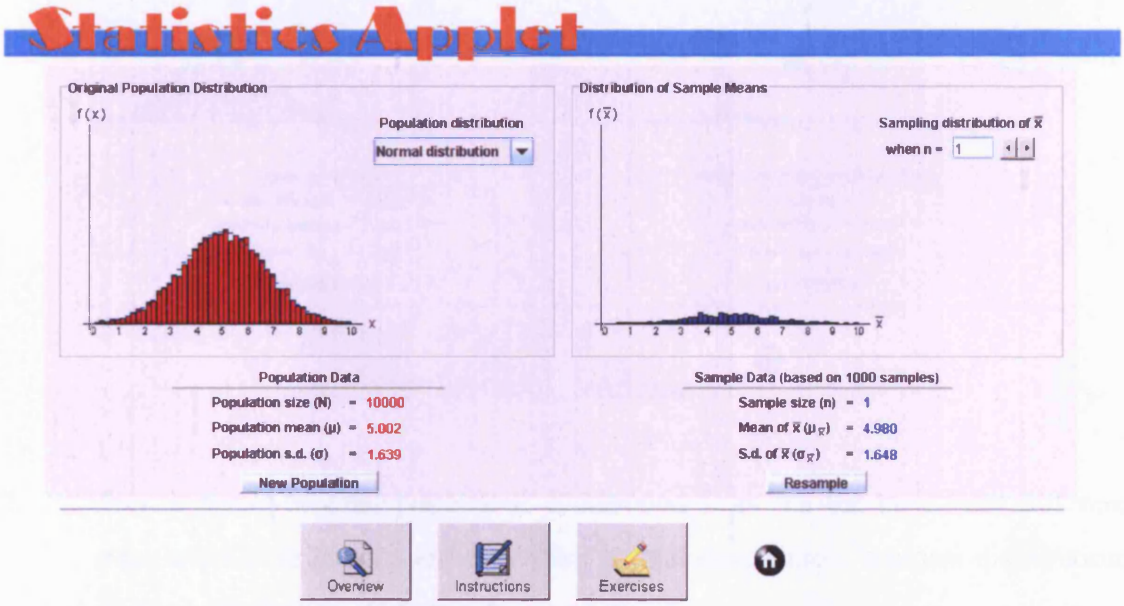
Very high. Students often find it very difficult to understand the concept of the Central Limit Theorem. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of sampling distribution and the theory of Central Limit Theorem. In designing this applet, pull-down menu and a few one-click buttons were deployed to create immediate visualisation. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to apply the Central Limit Theorem.

Objective

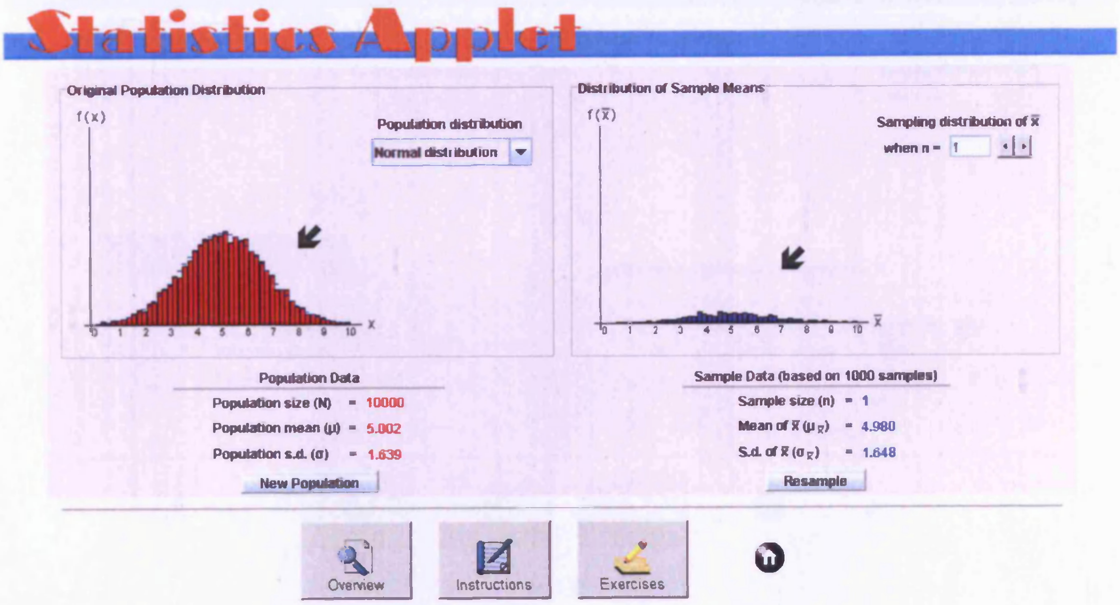
This applet is designed to help students to explore and discover the Central Limit Theorem concepts visually and interactively. The applet interacts with the student to get the student to select a population distribution and then drawing the sampling distribution of the sample means.

Instructions

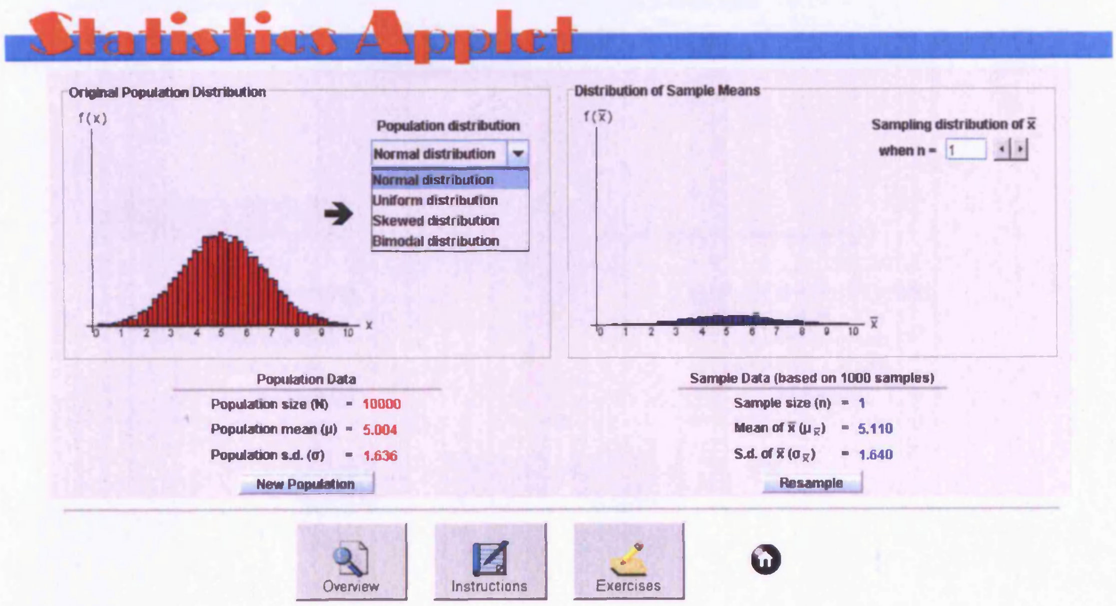
When the applet is loaded, the opening screen will appear as:



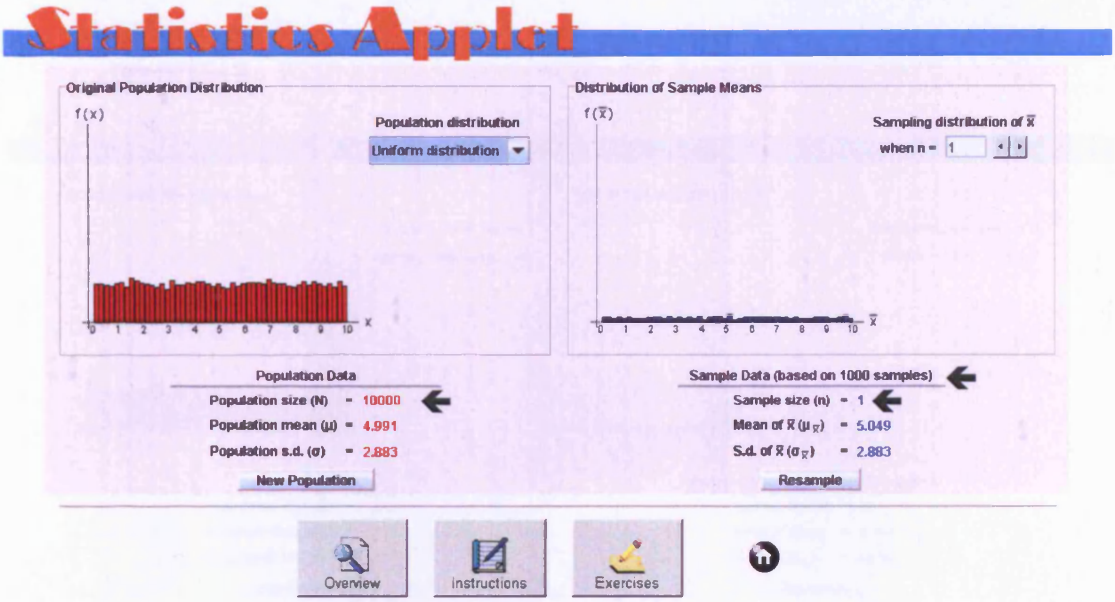
1. The applet has two windows. In the upper-left window, the histogram (in red) of the original population distribution is shown. The upper-right window shows the histogram (in blue) of the distribution of the sample means using 1000 samples of the specified size.



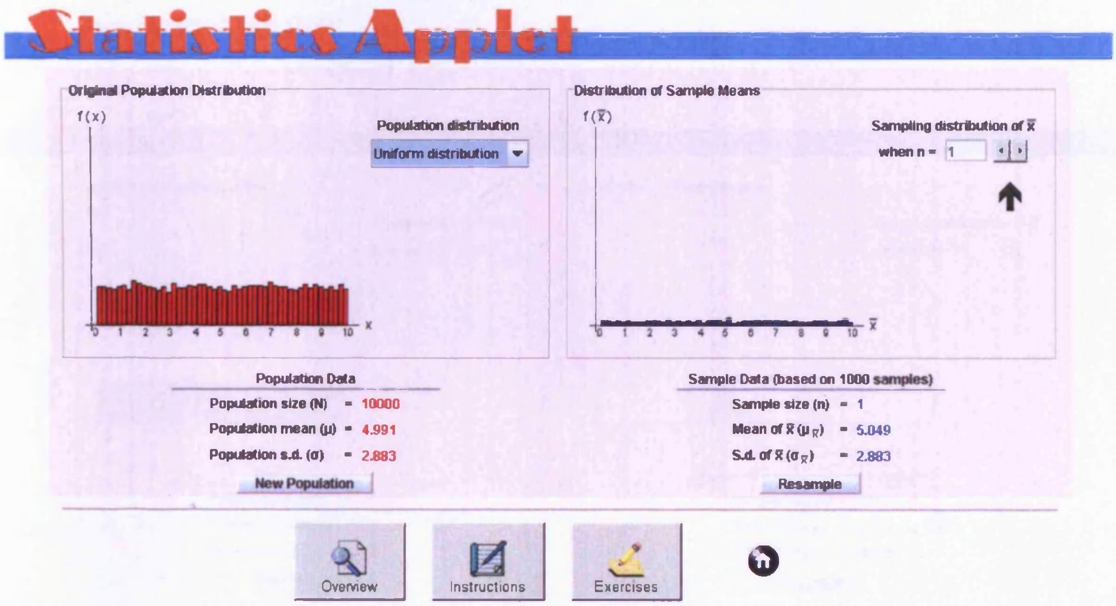
2. Pick a parent/original population distribution from the list box. Four different population distributions are available: normal distribution, uniform distribution, skewed distribution, and bimodal distribution.



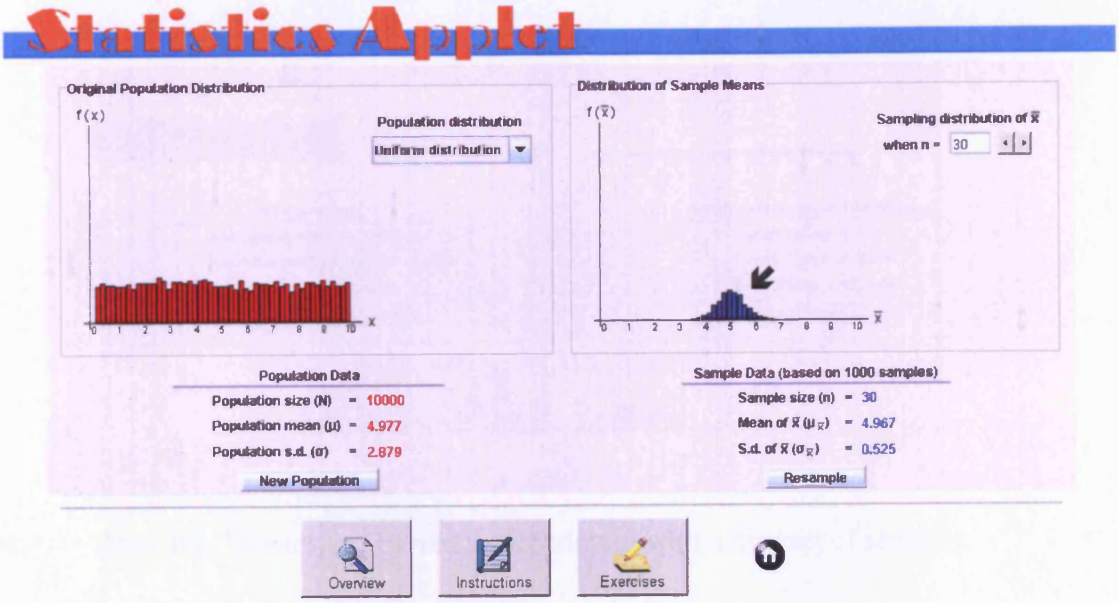
3. The applet first generates a population of 10000 random scores and then allows the user to take 1000 samples from this population, each having a sample size that the user can specify himself. The default sample size is $n = 1$.



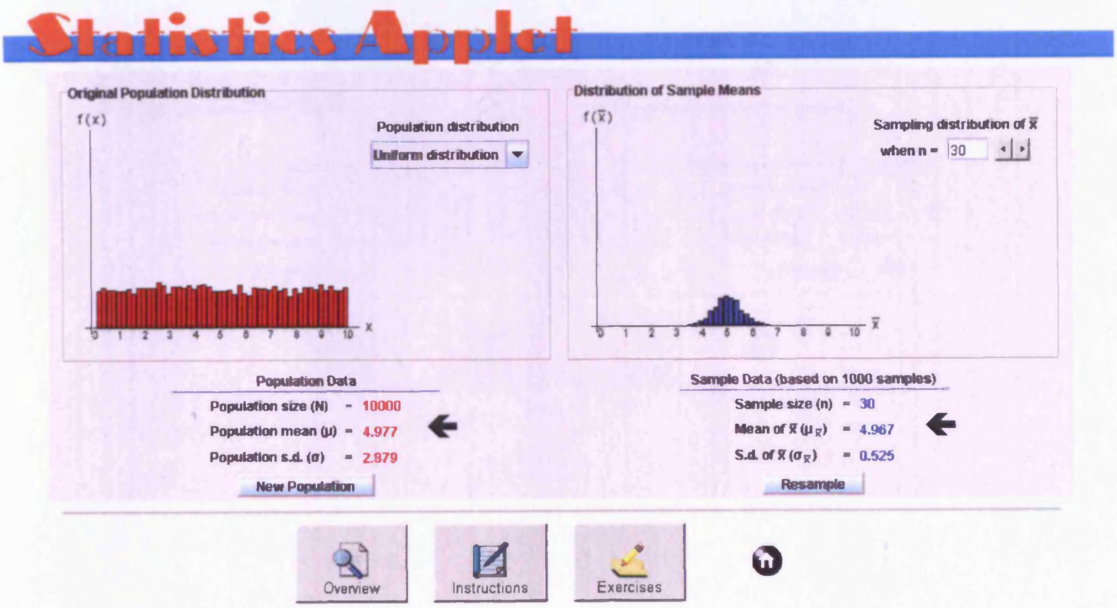
4. Click on the right arrow (▶) or the left arrow (◀) to increase or decrease the sample size n $(n = 1 \text{ to } 100)$ for each sample from the population.



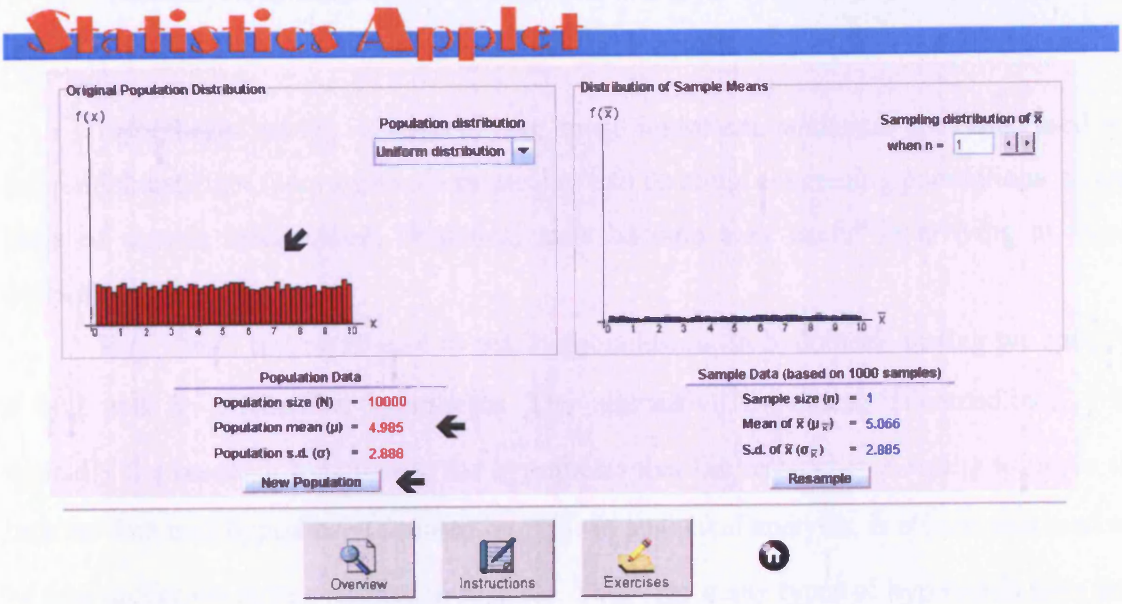
5. By changing the sample size n, the shape of the sampling distribution changes. Observe how when n is large, the histogram of the sampling distribution evolves to a shape close to the normal curve. [According to the Central Limit Theorem, the sampling distribution of the mean better approximates the normal distribution as n increases.]



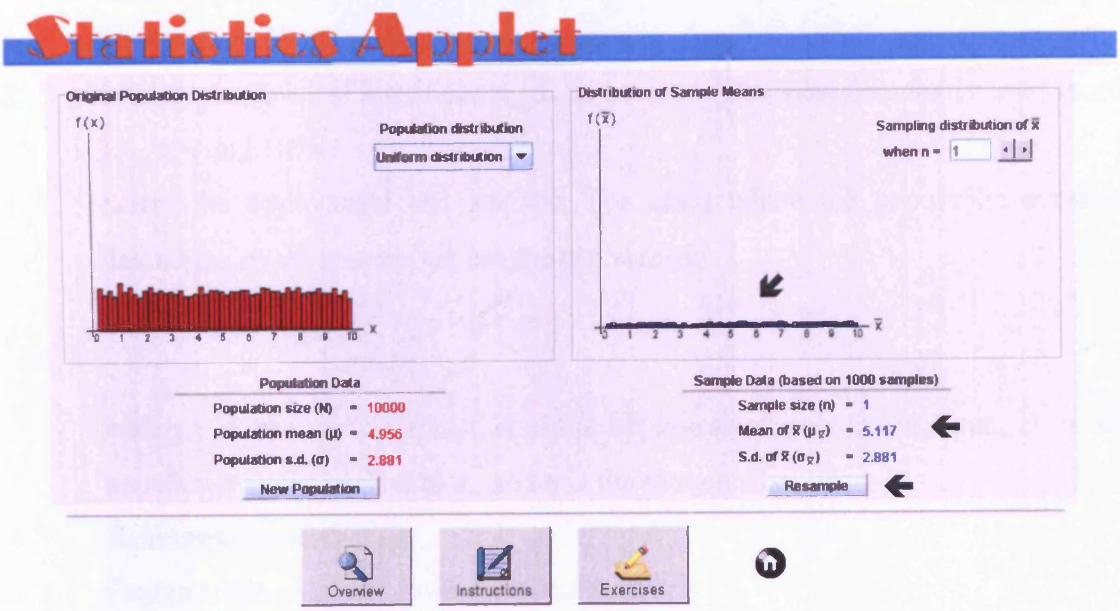
6. Summary statistics for the population data and the sample data are displayed under each window.



7. Press the "New Population" button to experiment with a new set of population data.



8. Press the "Resample" button to experiment with a new set of samples.



(iv) Hypothesis Testing Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/HypothesisTesting/HT.html

Overview

Hypothesis testing is one of the most important statistical methods used in inferential statistics. Very often, decisions have to be made concerning populations on the basis of sample information. Statistical tests become very useful in arriving at these decisions.

Hypothesis testing is used to reach a conclusion. In hypothesis testing we specify a null and an alternative hypothesis. The alternative hypothesis $(\text{denoted by } H_1)$ is typically the research hypothesis; the hypothesis that the researcher is trying to prove to be true. The null hypothesis$(\text{denoted by } H_0)$, in statistical analysis, is always assumed to be true unless we have evidence to reject it. There are many types of hypothesis tests but in here we shall focus on a 1-sample z-test for the value of the population mean (μ) with known population standard deviation (σ).

The general procedure for conducting a hypothesis test is listed below.

1. Define the null and alternative hypotheses.
2. Specify the level of significance, α, to be used. The most commonly used levels 1%, 5% and 10%.
3. Select the appropriate test statistic. For cases where the population standard deviation (σ) are known, we use the test statistic

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

   where $\bar{x}$ is the sample mean, μ is the hypothesized population mean, σ is the population standard deviation, and n is the sample size.
4. Determine the test value.
5. Find the critical values from statistical tables.
6. Use the decision rules to decide whether to reject the null hypothesis or not. The decision rule is to reject H_0 if the test value lies within the critical region; this is equivalent to saying that we would accept H_0 if the test value lies within the acceptance region.

Level of Abstraction of Underlying Concept

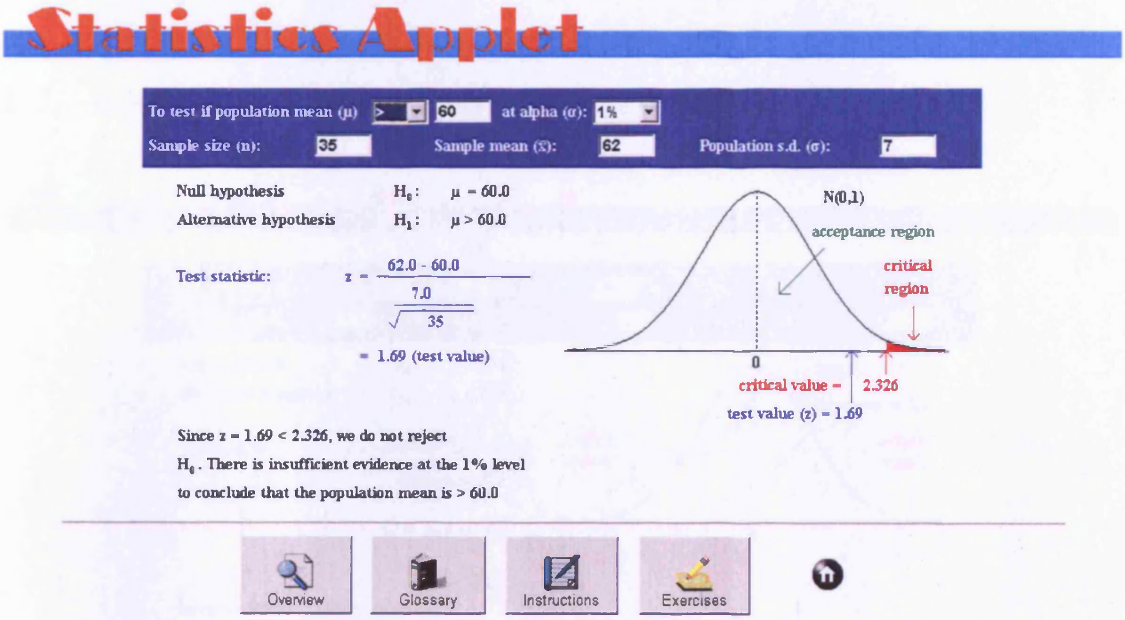
High. Students are often confused about when to accept or reject the null hypothesis. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of hypothesis testing. In designing this applet, pull-down menus and value boxes were deployed to create a dynamic and interactive learning environment. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to make decision based on hypothesis testing.

Objective

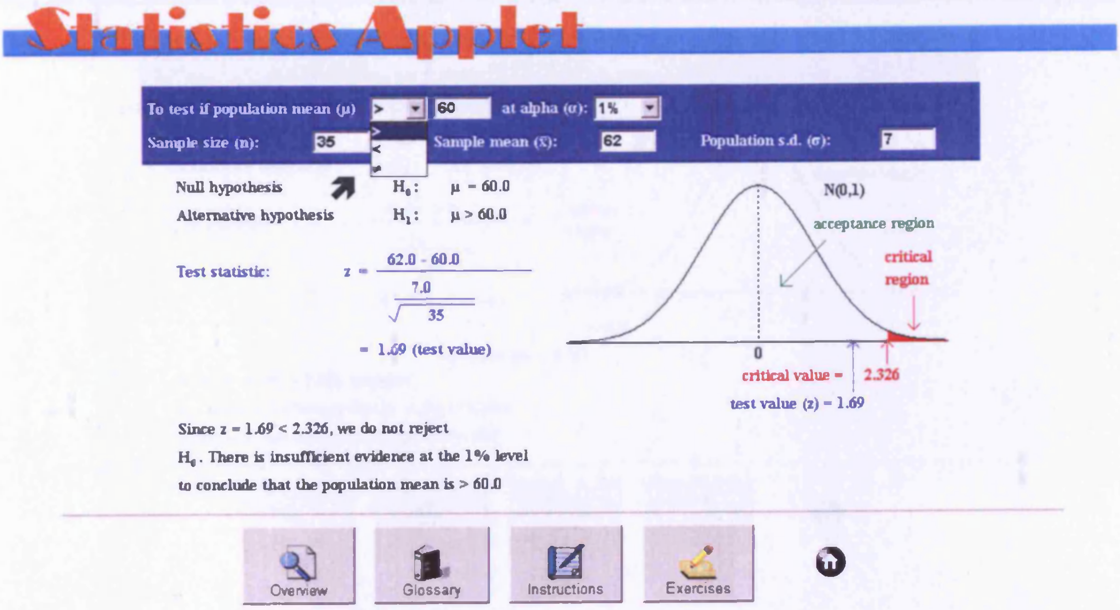
This applet is designed to demonstrate the principles of hypothesis testing using a test for a mean.

Instructions

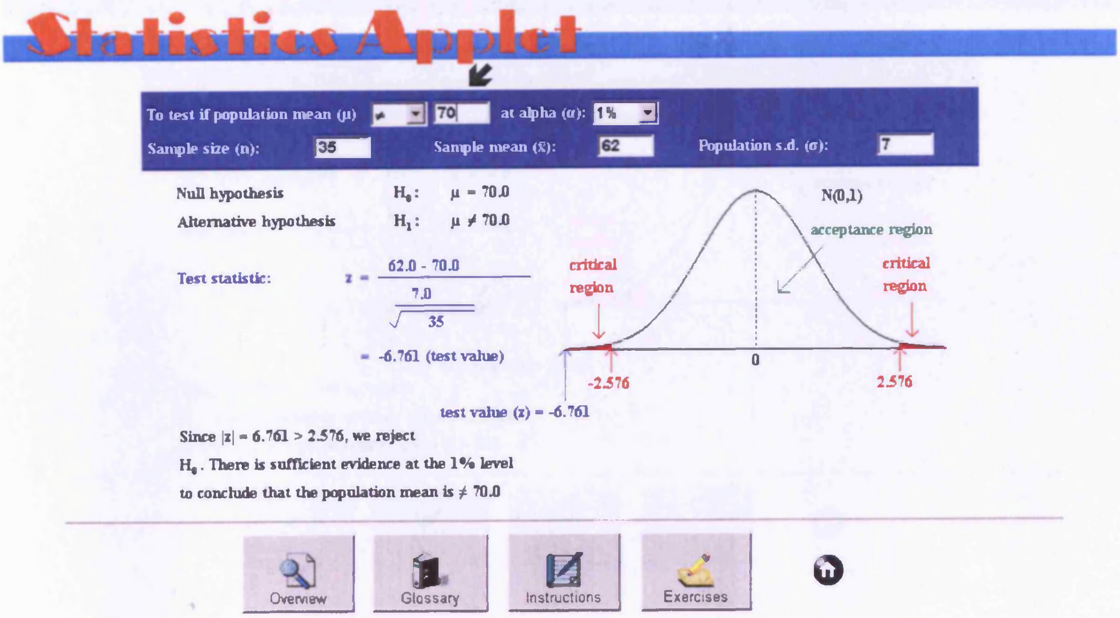
When the applet is loaded, the opening screen will appear as:



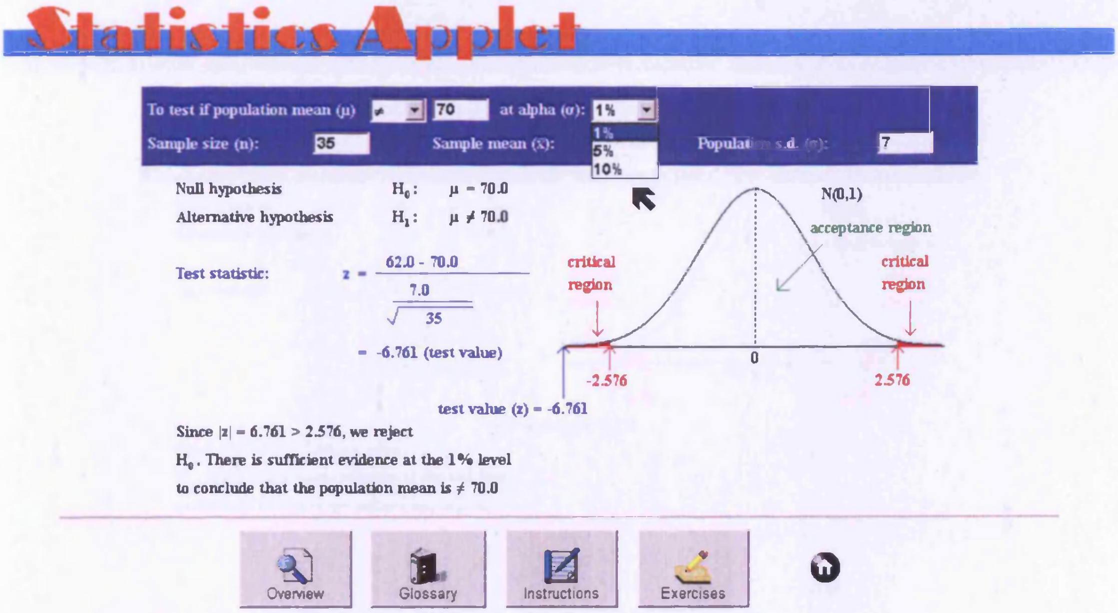
1. Select the type of alternative hypothesis (H_1). For one-tailed H_1, choose > or < symbol. For two-tailed H_1, choose $\neq$ symbol. The default is >.



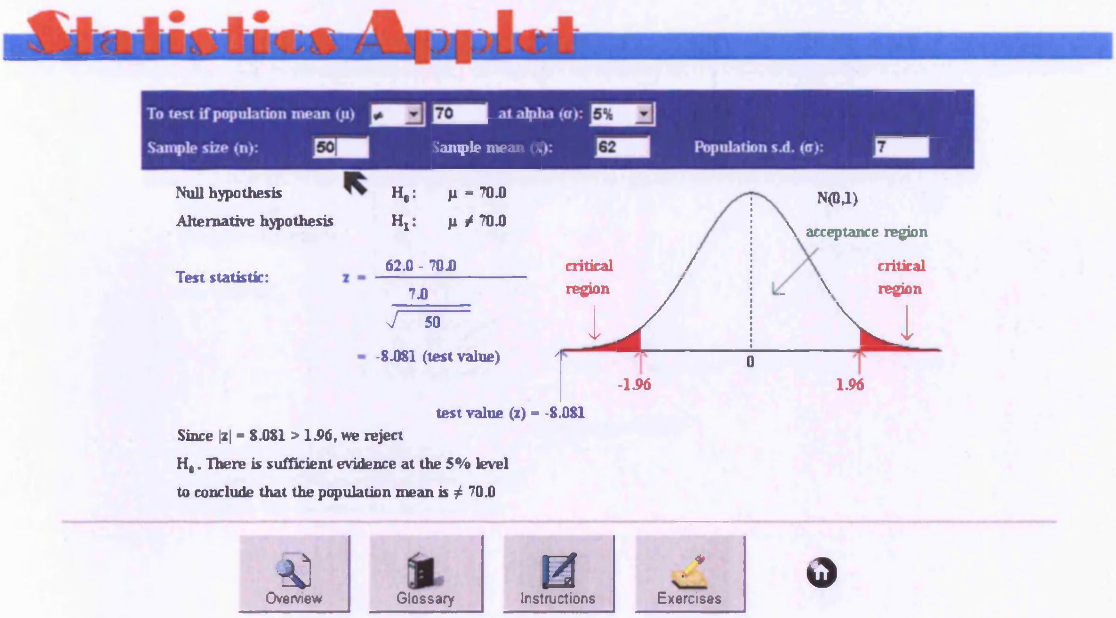
2. Input a value for the population mean (μ). The default is 60.



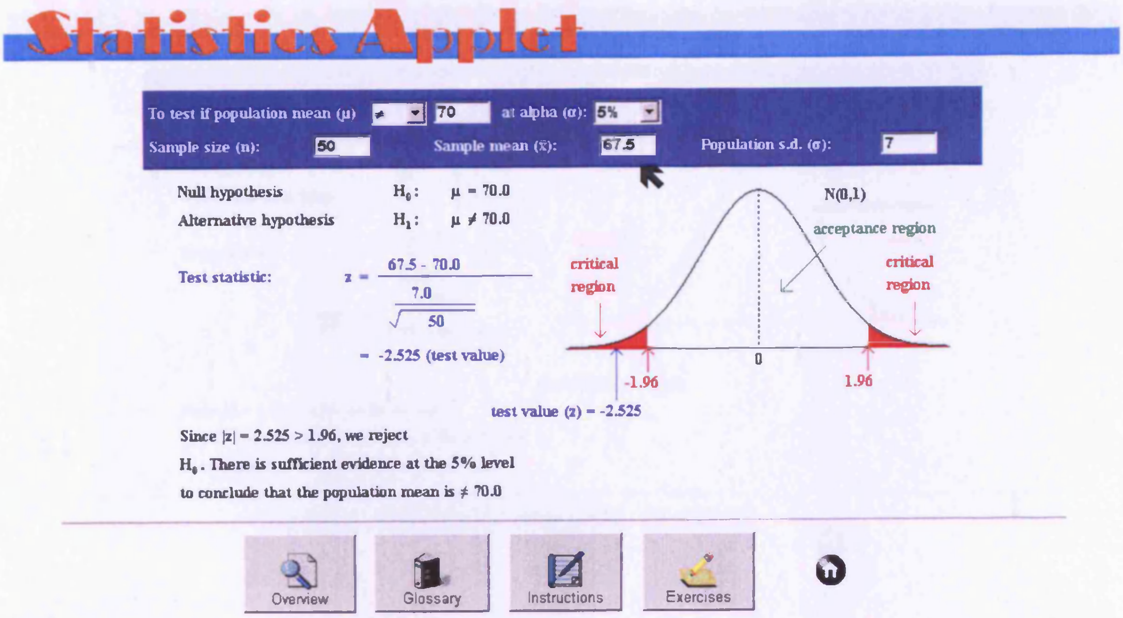
3. Select the level of significance (α): 1%, 5% or 10%. The default is 1%.



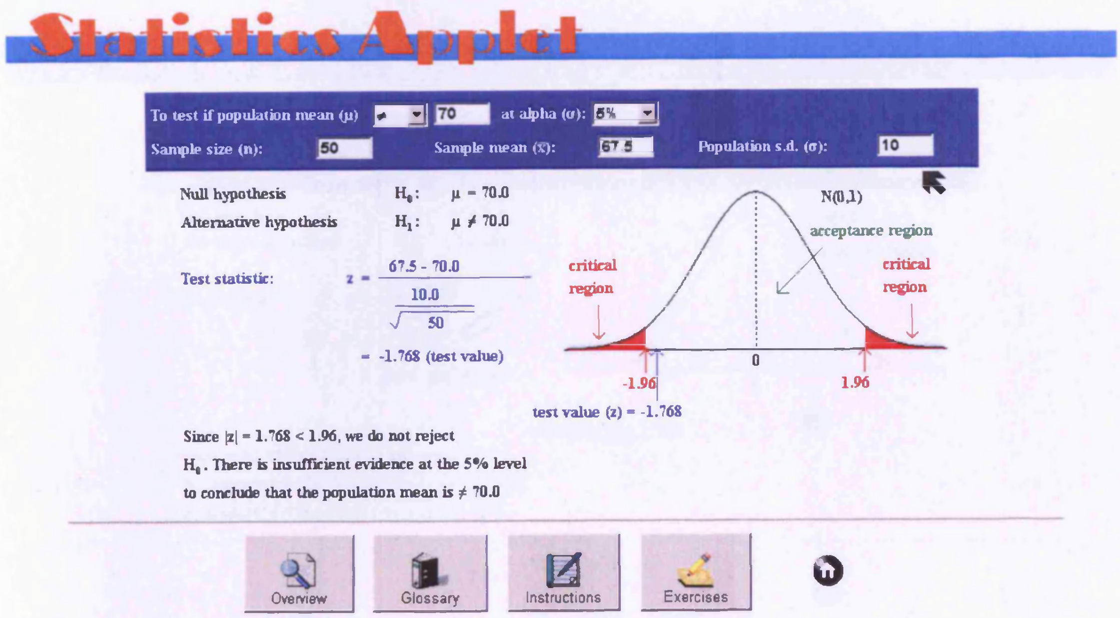
4. Input a value for the sample size (n). The default is 35.



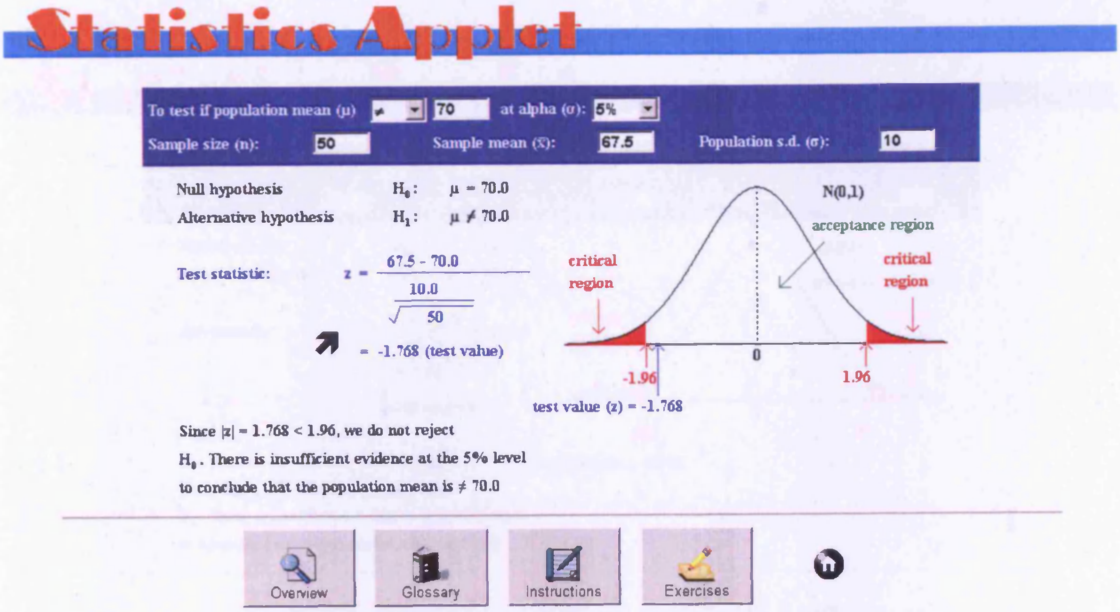
5. Input a value for the sample mean $(\bar{x})$. The default is 62.



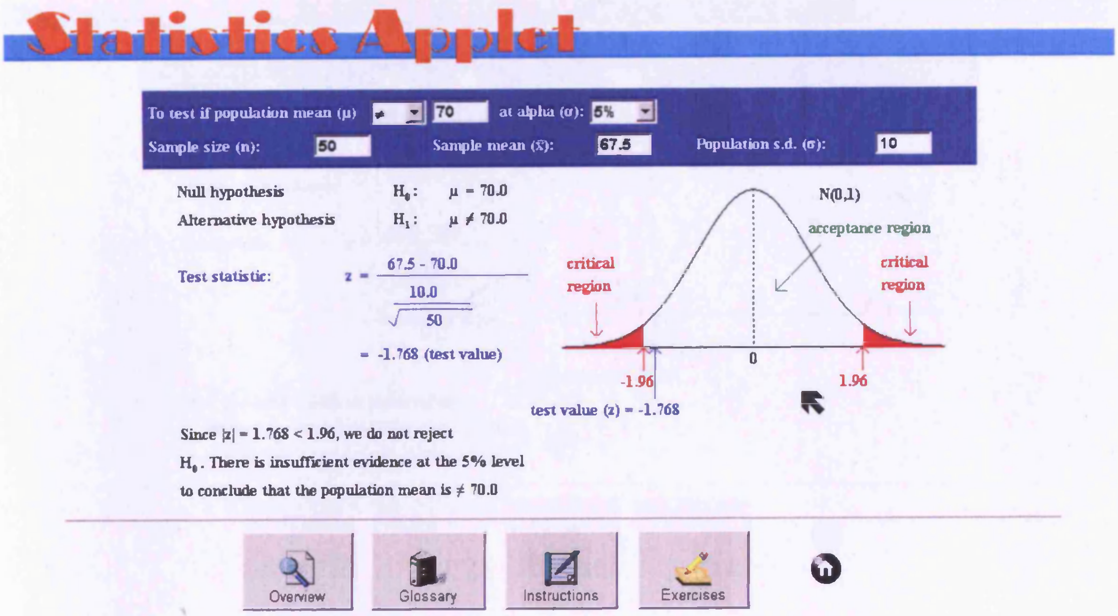
6. Input a value for the population standard deviation (σ). The default is 7.



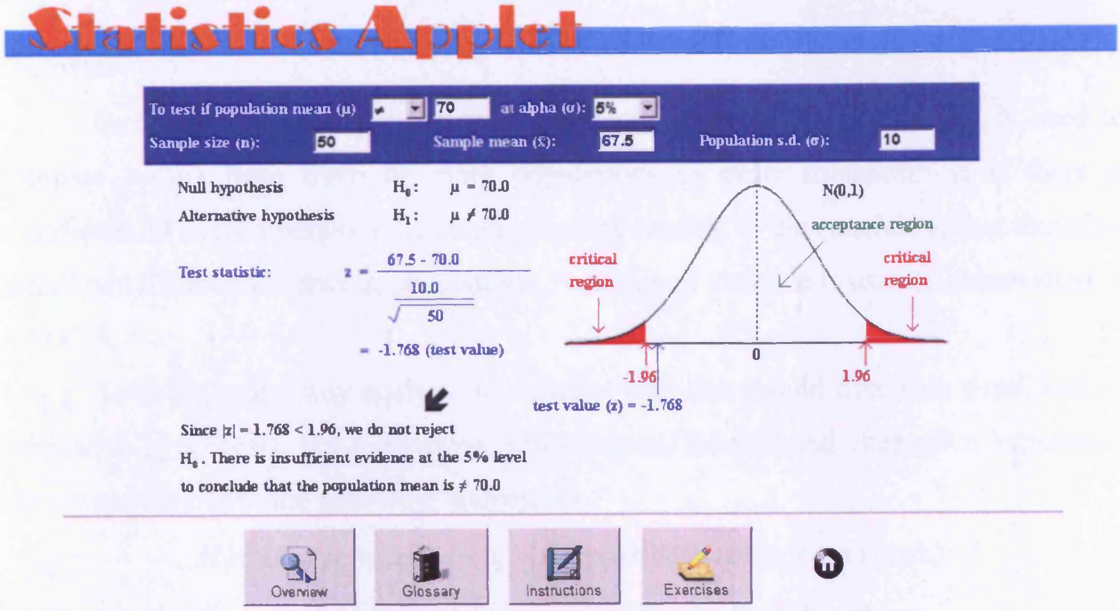
7. The test statistic and the test value will be dynamically updated.



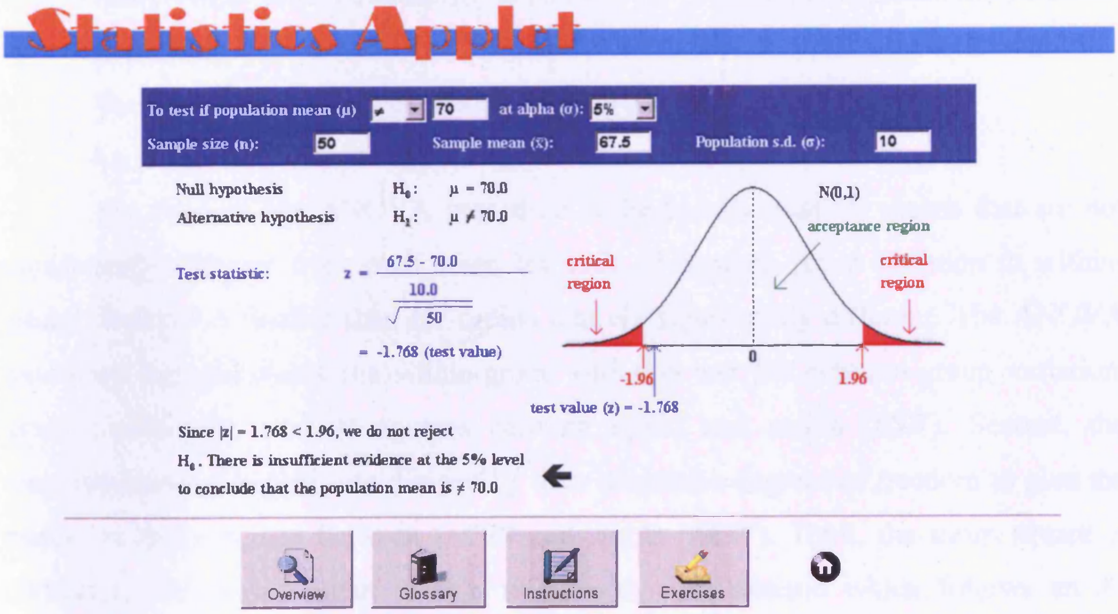
8. The diagram displaying the acceptance region, the critical region, the test value and the critical value will be dynamically updated.



9. The decision, whether to reject the null hypothesis or not, will be dynamically updated.



10. The conclusion will be dynamically updated.



(v) One-way ANOVA Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/Anova/Anova.html

Overview

One-way analysis of variance is a hypothesis-testing technique that is used to compare means from three or more populations in order to determine if there is significant difference between the means, thereby leading to the conclusion that there is a significant difference between populations. Analysis of variance is usually abbreviated as ANOVA.

To begin a one-way analysis of variance test, one should first state a null and an alternative hypothesis. For a one-way ANOVA test, the null and alternative hypotheses are always similar to the following statements.

$H_0: \mu_1 = \mu_2 = \mu_3 = \cdots \mu_k$ (All population means are equal.)

$H_0:$ At least one of the means is different from the others.

To use a one-way ANOVA test, the following conditions must be met.

1. Each sample must be randomly selected from a normal, or approximately normal, population.
2. The samples must be independent of each other.
3. Each population must have the same variance.

The basis of the ANOVA procedure is the premise that for means that are not significantly different from each other, the ratio of between-group variation to within-group variation is smaller than for means that are significantly different. The ANOVA procedure first calculates the within-group variation and the between-group variation, usually called the sum of squares between (*SSB*) and within (*SSW*). Second, the respective sum of squares are divided by their respective degrees of freedom to give the respective mean square between (*MSB*) and within (*MSW*). Third, the mean square is divided by the mean square within to give the test statistic which follows an *F*-distribution. The test statistic is

$$F = \frac{MSB}{MSW}$$

Level of Abstraction of Underlying Concept

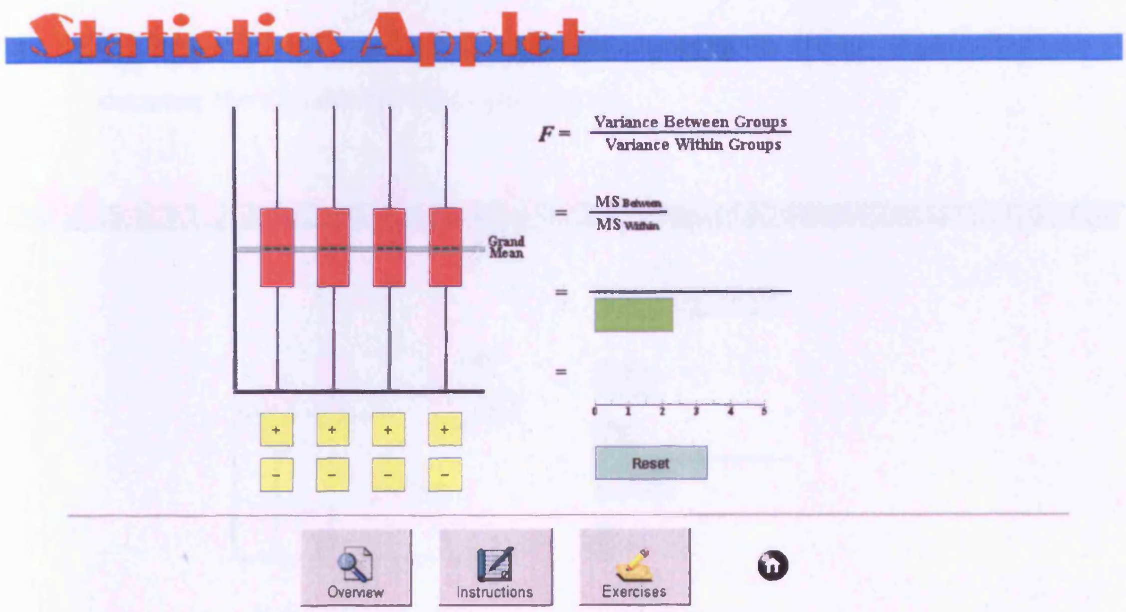
Very high. Students are often confused with the concept of variation between and within groups. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of Analysis of Variance. In designing this applet, a scroll bar and many buttons were deployed so that the effect of the changes can be seen immediately. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to perform the F-test.

Objective

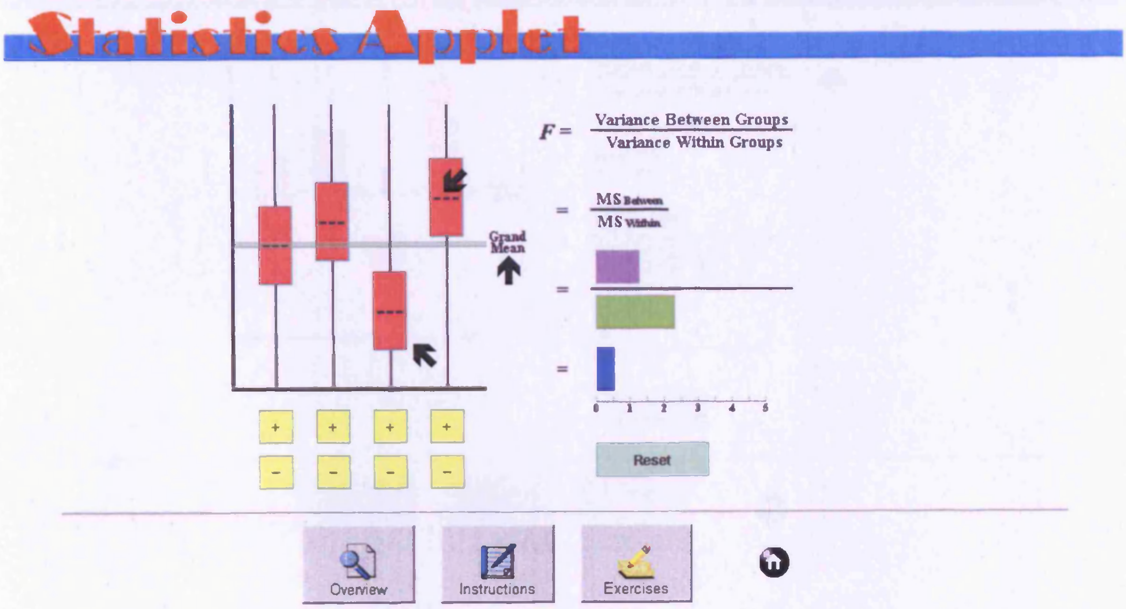
This applet is designed to demonstrate how variability between groups and variability within groups interact to change the value of the F ratio. Other than the scale below the purple bar, there are no numbers. The purpose of this applet is to get away from all the convoluted words and complex calculations and provide students with some experience of playing visually with the holistic ideas which give all these numbers and words meaning.

Instructions

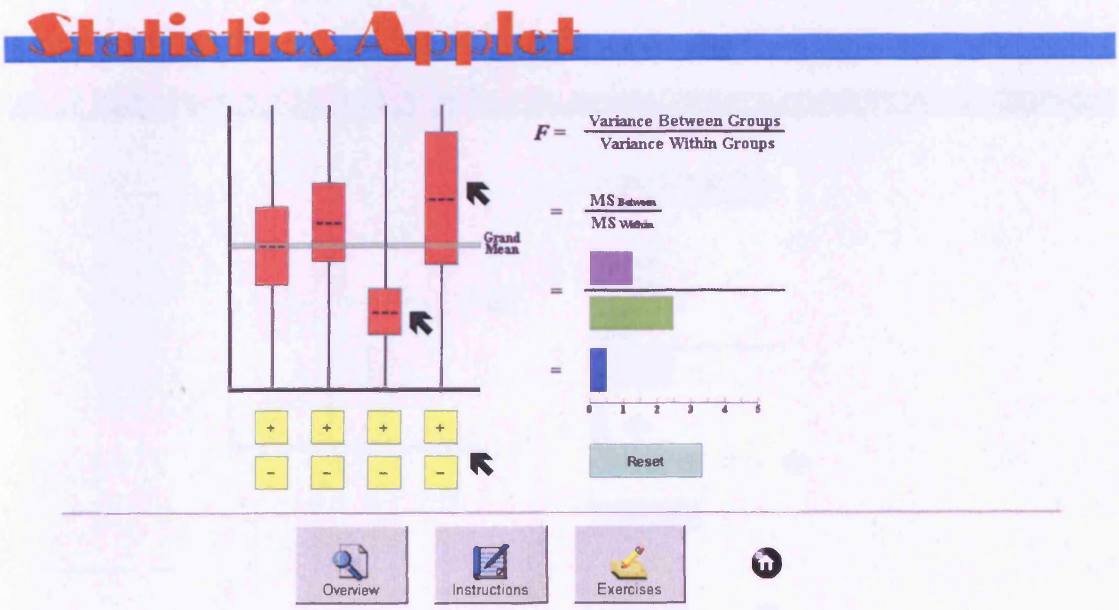
When the applet is loaded, the opening screen will appear as:



1. Click and drag the red rectangles on the graph. Doing so will allow you to move each group mean (the black dashed-line in the middle of each rectangle) up or down. Then the variability between the group means can be increased or decreased. The mean of the group means (the Grand Mean) is represented by a long light green line across the whole graph.

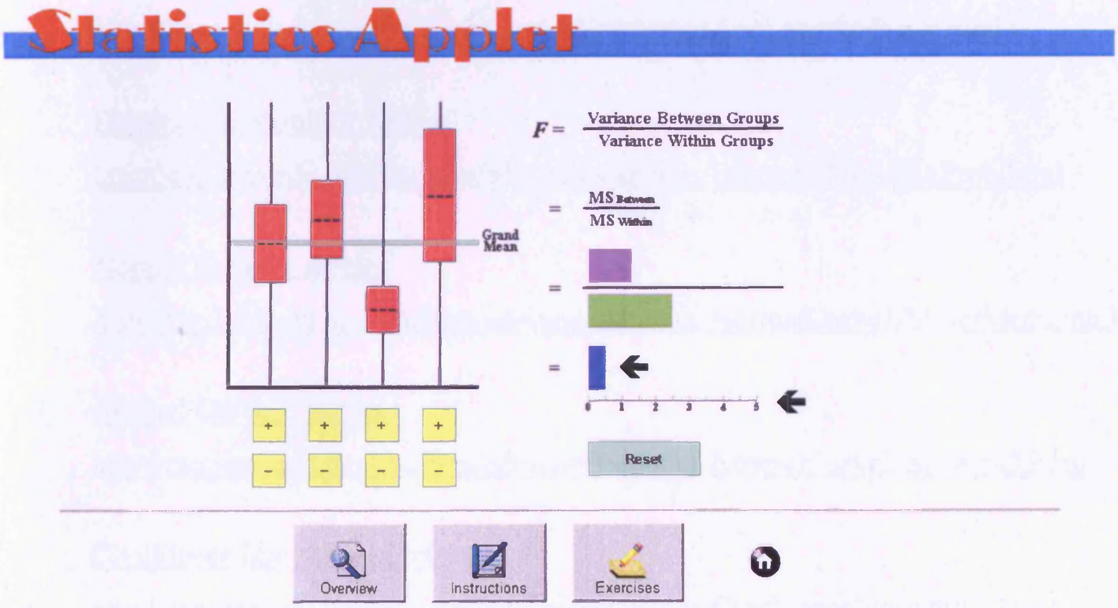


2. Click on the yellow + and – buttons for each group. Doing so will increase or decrease the variability within each group.

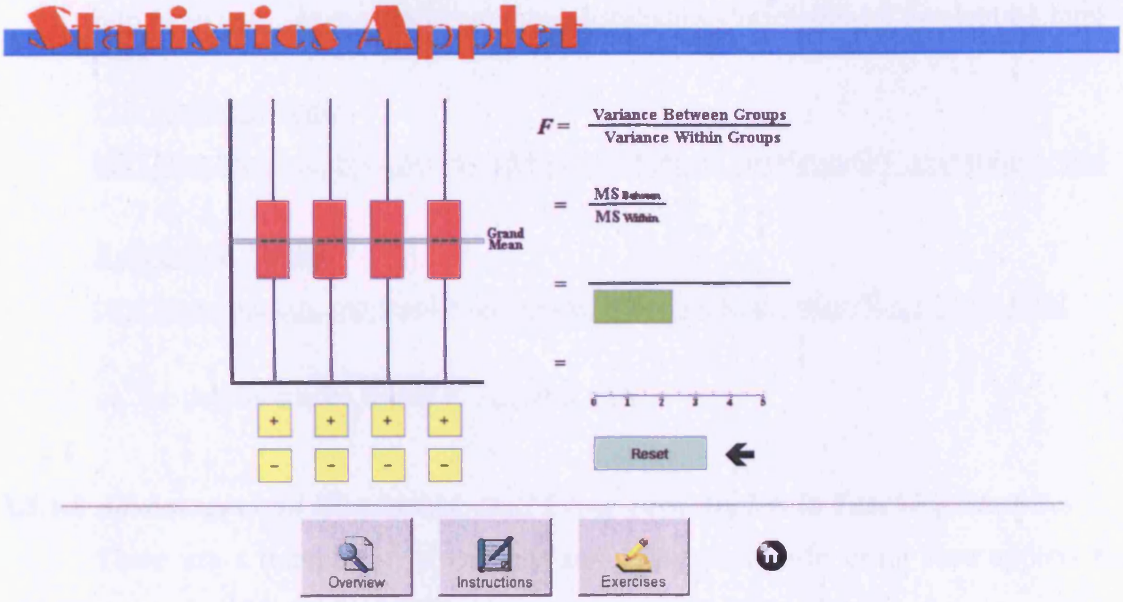


3. You can see a conceptual formula for F. Conceptually, the F ratio is the variability between groups divided by the variability within groups or *MSB* divided by *MSW*. This F ratio is represented visually as length of a purple bar divided by the length of a green bar.

4. The value of F is represented by a large blue bar. There is a scale from 0 to 5 below the blue bar so you can have some sense of how large the F value is. [For illustration purpose, F can only vary from 0 to 5. In reality, F can actually vary from 0 to infinity.]



5. Press the “Reset” button to start over again.



The remaining 10 applets can either be accessed directly from the following URL:

Histogram Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/Histogram/Histogram.html

Addition Law of Probability Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/OrLaw/OrLaw.html

Multiplication Law of Probability Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/AndLaw/AndLaw.html

Binomial Probability Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/BinomialProb/BinProb.html

Normal Curve 1 Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/NormalCurve1/SliderMean.html

Normal Curve 2 Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/NormalCurve2/SliderSD.html

Confidence Interval Applet

http://csp.ipm.edu.mo/teachers/edmund/statistics/ConfidenceInterval/CI.html

Correlation 1 Applet
http://csp.ipm.edu.mo/teachers/edmund/statistics/Correlation1/Correlation1.html

Correlation 2 Applet
http://csp.ipm.edu.mo/teachers/edmund/statistics/Correlation2/Correlation2.html

Regression Applet
http://csp.ipm.edu.mo/teachers/edmund/statistics/Regression/Regression.html

or, the details can be found in Appendix C.

3.5.1.2 *Advantages and Disadvantages of Using Java Applets in Teaching Statistics*

There are a number of advantages and disadvantages to using Java applets for teaching purposes (Kamthan, 1999).

Java applets have the following advantages:

- Students can input and change data dynamically and see the result
- Students can learn using dynamic, graphics capabilities and visualizations
- Students can be more efficient at interacting with core concepts using applets
- Being platform independent and portable, applets can be used on virtually any system
- Once the Java Virtual machine (JVM) is running secondary applets run faster and load more quickly
- Applets support distributed and Network computing
- All necessary components (Main programme + Graphics + User interface) of an application are embedded in a single environment
- Java-compliant *WWW* browsers as well as Java complier, runtime environment are freely available

Some disadvantages of using Java applets include the following:

- Often a lack of resources in creating, developing and maintaining Java applets significantly slows down the development of learning materials and knowledge transfer
- Java-based programming is quite difficult to master and requires a high level of programming skill to complete work in
- Applets are supposed to be compatible with most browsers that are Java enabled. But unfortunately there are some applets that do not run properly, even on browsers like Netscape or Explorer
- Applets require the Java plug-in, which typically is not available automatically in all Web browsers
- Depending on the size of the applet, the downloading time might be a little long. Applets must be completely downloaded and installed before they function normally
- There is no control over the performance of applets as their execution time will vary by the type of system being used and the operating system in place

3.5.2 Traditional Classroom Teaching Method

The traditional class followed the conventional teaching methods in introductory statistics classes with direct teaching, classwork, homework reviews, whiteboard or overhead projector demonstrations and so on.

The traditional classroom instruction creates a teacher-centred learning environment. The aim is to produce quality instruction. Knowledge exists outside the mind of the student, and is transferred or delivered from the teacher to the students. New information is added on top of existing knowledge. The learning experience is competitive. The competition is often between students. Under this approach, the teacher is in control and he/she is the knowledge giver and students are often passive recipients of knowledge.

Table 3 summarizes the similarities and differences between the two classes.

Table 3: *Comparison of Course Features*

Feature	Applet-based Class	Traditional Class
Semester offered	Fall 2006	Fall 2006
Lecture times	Tuesdays and Thursdays 2:30 – 4:00 PM	Mondays and Wednesdays 9:30 – 11:00 AM
Instructor	Edmund Yung	Edmund Yung
Number of days of instruction	30	30
Credits	3	3
Class size	37	38
Venue	Laboratory	Classroom
Examination	Final examination	Final examination
Homework	Assigned and due weekly	Assigned and due weekly
Textbook	*Applied Statistics for Engineers and Scientists*	*Applied Statistics for Engineers and Scientists*
Computer use	One computer for each student	None

Key elements associated with applet-based and traditional classroom instructional approaches are compared in Table 4.

Table 4: *Comparison of Two Instructional Approaches*

Element	Applet-based Class	Traditional Class
Learning theory	Constructivism	Objectivism
Learning environment	Student-centred environment	Teacher-centred environment
Instructional goal	Improve student learning	Produce quality instruction
Existence of knowledge	Internally, knowledge exists inside student's mind	Externally, knowledge exists outside students' mind
Acquisition of knowledge	Knowledge is constructed and created by students themselves	Knowledge is transferred or delivered from teacher to students
Learning experience	Learning is interactive and collaborative	Learning is competitive
Taking control	Students control their own learning	Teacher controls the learning activities
Teacher's role	Facilitator of learning	Disseminator of knowledge
Students' role	Active constructors of knowledge	Passive recipients of knowledge

3.6 RESEARCH INSTRUMENTS

In all, six instruments were designed to gather data for this study, one of these measured demographic data, two measured content knowledge, two measured student attitude, and one measured student satisfaction.

3.6.1 Demographic Characteristics

At the beginning of the class meeting prior to teaching, a demographic questionnaire was distributed to capture student demographic information regarding gender, age, prior grade point average (GPA), comfort with computers and previous statistics experience.

3.6.2 Student Achievement

To assess student performance, the instructor gave the Java applet-based and traditional class sections identical pre-tests and post-tests. These instruments measured statistical knowledge before and after instruction. After the class meeting, students completed the pre-test measures prior to the lecture. Students completed the instrument post-test at the conclusion of the course. The pre-tests and post-tests consisted of 50 multiple-choice items and each item had four alternative answers. Each correct answer was worth 2 points, and each incorrect answer was 0 point. The pre-test and post-test were similar in content but with a different question sequence.

Validity refers to the extent to which the test actually and accurately measures what it purports to measure. Content validity was accomplished on both the pre-test/post-test test instruments through a formal review by a panel of two statistics subject matter experts. These experts assessed how well the test items correspond with the course domain. This process resulted in some minor changes in the wording of some test items without elimination.

Reliability refers to the consistency of test results. Reliability coefficients range from a low of 0.00 (no reliability) to a high of 1.00 (perfect reliability). The higher the value of the coefficient, the more confidence one can have in the usefulness of the test data for making decisions. One of the most frequently used reliability coefficients is Cronbach's Alpha (Norusis, 1990). Cronbach's Alpha was calculated for each of these two tests. The Alpha of these tests were: Pre-test, 0.828; Post-test, 0.831.

3.6.3 Student Attitude

To evaluate student attitude, students in the Java applet class completed two standardized, twenty-question Attitudinal Evaluation forms. These instruments measured students' attitudes before and after the instruction. Students completed the pre-instruction attitudinal survey at the end of the class meeting immediately prior to the lecture. Students completed the post-instruction attitudinal survey at the conclusion of the course. These attitudinal questions employed a five-item Likert-type response scale. Cronbach's Alpha was calculated for each of these two surveys. The Alpha of these surveys were: Pre-instruction attitudinal survey, 0.865; Post-instruction attitudinal survey, 0.834.

3.6.4 Student Satisfaction

To evaluate student satisfaction, participants completed a standardized, twenty-question Course and Instructor Evaluation Form. This instrument employed a five-item Likert-type response scale ranging from strongly agree to strongly disagree on the first eighteen questions. The reliability of these eighteen questions on the instrument was found to be Alpha = 0.932. Students responded to questions focusing on the effectiveness of the instructor, perceived quality of the course material, the perception of value from the lecture, and the relative level of confidence with new statistical concepts. The ability to follow the lectures and their content was also specifically tested as well. The final two questions were open-ended questions, namely, (a) "Give important aspects of this course." and (b) "Provide constructive and actionable suggestions for course improvement.".

3.7 ETHICAL ISSUES

Ethics is important to all parties because it affects the rights of individuals and ultimately the quality of the data obtained from inquiry. Two safeguards were taken in this study to protect the informants' rights.

3.7.1 Informed Consent

An informed consent form (see Appendix E) was distributed to each student prior to the research. All students had the right to withdraw from the study at their discretion.

3.7.2 Anonymity

This was guaranteed to students as they would be coded numerically in order to eliminate identifying features from the data during data preparation and entry. No student was identified in the study or in the reporting of the study. Access to data gathered was treated very carefully and would only be available to the researcher and his EdD supervisor.

3.8 VALIDITY CHECKS

Experiments are judged by two measures of validity. One is internal validity. The second is external validity.

3.8.1 Internal Validity

Internal validity refers to the extent to which the experimental intervention (use of Java applets) was the sole cause of observed changes in the dependent variable (post-test scores).

There were eight possible threats to internal validity (see Table 5): history, maturation, testing, instrumentation, statistical regression, selection, experimental mortality and design contamination.

Table 5: *Threats to Internal Validity*

Possible Threats to Internal Validity	*Controlling for Threats*
History Both significant and insignificant events outside the investigation may affect the results of the study.	No apparent threat noted, because both groups experienced the same current events.
Maturation The function of natural and predictable changes occurring in participants over time. These include aging and fatigue.	No apparent threat noted, because both groups experienced the same developmental processes.

Testing The effect of pre-testing in a before-and-after study may sensitize the participants when taking a test for the second time.	The pre-tests are likely to have sensitized the students to the post-test. Thus, testing effects would exist. However, if all the groups were given both the pre- and the post-tests, the testing effects across all groups would have been taken care of (i.e., nullified) and the post-tests of the experimental group could have been compared with that of the control group to detect the effects of the intervention.
Instrumentation Changes in the measurement instrument between the pre-test and the post-test.	Use of almost the same test for pre-test and post-test allows us to rule out instrumentation, so we do not expect instrumentation bias.
Statistical Regression The tendency for participants who are selected because they have extreme scores on a variable to be less extreme in a follow-up testing.	Though not specifically stated, we can presume that all the participants in the experiment were selected from a Normally distributed population, in which case, the question of statistical regression does not arise.
Selection A sample bias resulting in the differential selection of participants for the experimental and control groups.	Random assignment of participants was not feasible. However, no significant difference was found in the mean pre-test scores between the experimental group and the control group, so we do not expect selection bias to exist.
Experimental Mortality This refers to participants dropping out before the study is completed.	Since no students dropped out of the experimental and control groups, the question of mortality does not arise.

Design Contamination If participants in the experimental and control groups communicate, then those in the control group may learn of the intervention, this could decrease differences between the groups.	No apparent threat noted; however, if experimental-group members shared information with control-group members. Sharing should decrease differences between the experimental and control groups.
Resentful Demoralisation Participants in the control group may become discouraged because they are not receiving the special attention that is given to the experimental group.	No apparent threat noted; however, this threat can be controlled by avoiding experimental-group members and control-group members being in the same room.

3.8.2 External Validity

External validity refers to the extent to which the study's findings are generalizable, or applicable, to groups or environments outside the research setting.

No apparent threats noted; however, possible threats could be assumed easily.

One possible threat to external validity concerns the use of college students as experimental subjects. Students are easily accessible but often, they are not representative of the total population. However, in the evaluation of education programmes, the use of students as participants is unavoidable. Best evidence of this external validity would be replication of this evaluation study in other institutions of higher education.

Another possible threat to external validity is that the instructor may have been enthusiastic and committed because of his involvement in implementing a new intervention. However, any respectful instructor will teach the respective classes, no matter whether it is an experimental class or a control class, in an unbiased manner. In addition, after the examinations the test papers for both the experimental and control groups were pooled so that they were completely intermingled. Students only needed to fill in their student I.D. on each test paper and the student names were not recorded. The test papers were then given to the instructor for grading. After grading, student names were matched to test papers to record results. This procedure allowed the instructor to grade test papers from both classes without the instructor knowing from which class the test papers originated. This helped to eliminate potential instructor bias, either in favour of his students from the applet-based class or, conversely, in favour of his students from the traditional class.

3.9 DATA ANALYSIS

Both quantitative and qualitative methods were used to analyze the data. Data were statistically analyzed using the Statistical Package for the Social Sciences (SPSS), version 13 for the PC. Data collected from the questionnaires were imported into an SPSS data file for analysis. The pre- and post-test scores for each student were added to the file along with responses to the questionnaires. Once this process was completed, data was not associated with a student by name.

Descriptive statistics (means and standard deviations) were applied to selected demographic variables, pre-test, post-test, and also to each statement on the evaluation form. To show equivalency of groups, independent-samples *t*-tests and chi-square tests were used. Independent-samples *t*-tests analyses were conducted for quantitative data and chi-square analyses were conducted for qualitative data. Paired-samples *t*-tests were used to compare the performance within the two groups. In order to compare the examination scores of students in the Java applet-based instruction and traditional instruction groups, independent-samples *t*-tests were used. In addition, Analysis of Covariance (ANCOVA) was also performed, with the pre-test as the covariate (the pre-test was used as the covariate because how the participants score before interventions is generally correlated with how they score after interventions) and the post-test as the dependent variable, to ensure that any group differences found on the measures of achievement were not due to pre-existing group differences rather than to instructional methods. Multiple regression analysis was used to test whether the Java applets had any impact on student performance. Paired-samples *t*-tests were conducted to compare the pre-instruction attitude and the post-instruction attitude in the applet-based course. Independent-samples *t*-tests were also used to evaluate the overall quality of the instructor and the course across the experimental and control groups. An alpha level of 0.05 was used to determine significance. Some important results were generated.

CHAPTER 4

RESULTS

This chapter describes the findings of this study and will answer each of the research questions. The analysis of data and results are presented in thirteen sections. Section 4.1 gives the background characteristics of the participants. Section 4.2 provides a summary of findings for the equivalence of the two teaching method categories in light of background characteristics. Sections 4.3 and 4.4 contain the results of evaluating different types of student performance. Section 4.5 displays the relationships between variables through a correlation matrix. Section 4.6 presents the Analysis of Covariance (ANCOVA) results, and will answer the first specific research question, which reads: is there any statistically significant difference in the performance of students taught by Java applet-based instruction compared with those taught by traditional classroom instruction? The results of the multiple regression analysis can be found in Section 4.7. Section 4.8 contains the results of evaluating the student attitude, and will answer the second specific research question, which reads: is there any statistically significant difference in student attitude, before and after course completion, for students taught by Java applet-based instruction? Section 4.9 gives the results of evaluating the student satisfaction, and will answer the third specific research question, which reads: is there any statistically significant difference in student satisfaction for students taught by Java applet-based instruction compared with those taught by traditional classroom instruction? Section 4.10 contains a complete listing of student responses as reported on the questionnaire, and will answer the fourth specific research question, which reads: what kind of opinions do the students express of interactive applets? Section 4.11 explains why Java applets are used to teach statistics, which will provide an answer to the fifth specific research question, which reads: why should statistics instructors use applets in teaching? Section 4.12 provides a summary of the advantages and disadvantages of learning using interactive applets, which will provide an answer to the fifth specific research question, which reads: what kinds of advantages and disadvantages appear in learning through interactive applets? Section 4.13 is concerned with using Khan's WBL framework to examine the instructional effectiveness of the Java applet-based learning environment, and will answer the sixth specific research question, which reads: according to Khan's WBL framework, does the Java applet-based instructional approach create a meaningful learning experience?

The purpose of this quantitative study was to investigate the influence of a particular teaching methodology on student achievement, attitude and satisfaction. Specifically, two categories of teaching methods were used, Java applet-based instruction and traditional instruction. The dependent variable for this analysis was the post-test score for each participating student. The results of this analysis are offered here.

4.1 DESCRIPTION OF THE PARTICIPANTS

Descriptive statistics and measures of dispersion were calculated to represent the background characteristics of participating students, as reported in the demographic questionnaire. Mean scores were calculated for quantitative data, including GPA and age. Table 6 displays the background characteristics of participating students. Percentages were used to describe qualitative data, such as gender, the degree of comfort with computers and previous experience of statistics.

Table 6: *Demographics of Participating Students*

Characteristic	Applet-based ($n = 37$)		Traditional ($n = 38$)		Total ($n = 75$)	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
GPA	2.98	0.47	3.06	0.53	3.02	0.50
Age	19.86	1.34	19.95	1.39	19.91	1.36
	#	%	#	%	#	%
Gender						
Male	24	64.9	27	71.1	51	68.0
Female	13	35.1	11	28.9	24	32.0
Comfort with Computers						
Very Uncomfortable	2	5.4	1	2.6	3	4.0
Uncomfortable	5	13.5	7	18.4	12	16.0
Uncertain	9	24.3	9	23.7	18	24.0
Comfortable	9	24.3	17	44.7	26	34.7
Very Comfortable	12	32.4	4	10.5	16	21.3
Previous Statistics Experience						
None	2	5.4	2	5.3	4	5.3
Only a Little	5	13.5	2	5.3	7	9.3
Some	10	27.0	7	18.4	17	22.7
A Considerable Amount	9	24.3	15	39.5	24	32.0
A Great Deal	11	29.7	12	31.6	23	30.7

Two intact sections were randomly selected and assigned to either an experimental group (applet-based instruction; $n = 37$) or a control group (traditional instruction; $n = 38$). The overall sample consisted of 75 students. Sixty-eight percent of the participants were male $(n = 51)$. The average age of the participants was 19.91 years $(\text{s.d.} = 1.36)$ with a range of 18 to 23. The mean grade point average (G.P.A.) was 3.02

$(\text{s.d.} = 0.50)$ on a 4-point scale, with a range of 2.1 to 3.9. The majority felt that they were either comfortable or very comfortable with computers $(56.0\%,\ n = 42)$. Fifteen percent reported that they either had no or only a little previous statistics experience $(n = 11)$; 23% indicated that they had some $(n = 17)$; and 63% said that they either had a considerable amount or a great deal of previous statistics experience $(n = 47)$.

4.2 EQUIVALENCE OF GROUPS

To show equivalence across groups, *t*-tests and chi-square tests were used. A *t*-test was the primary method of analysis used to test for differences between quantitative / numerical data. A chi-square test was the primary method of analysis used to test for independence between qualitative / categorical data.

Independent-samples *t*-tests indicated that the distribution of grade point average and age did not differ for the applet-based and the traditional groups: grade point average, $t(73) = -0.61$, $p = 0.54$; age, $t(73) = -0.26$, $p = 0.79$.

A Chi-square analysis indicated that the distribution of gender, comfort with computers, and previous statistics experience did not differ for the applet-based and the traditional groups: gender, $\chi^2(1,\ N = 75) = 0.33$, $p = 0.57$; comfort with computers, $\chi^2(4,\ N = 75) = 7.12$, $p = 0.13$; previous statistics experience, $\chi^2(4,\ N = 75) = 3.35$, $p = 0.50$.

Results from the analyses of the student characteristics are presented in Table 7.

Table 7: *Mean and Percent Differences for Student Characteristics*

Characteristic	Applet-based		Traditional		*df*	*t*	*p*
	Mean	*s.d.*	*Mean*	*s.d.*			
GPA	2.98	0.47	3.06	0.53	73	−0.61	0.54
Age	19.86	1.34	19.95	1.39	73	−0.26	0.79
	n	%	*n*	%	*df*	χ^2	*p*
Gender							
Male	24	64.9	27	71.1	1	0.33	0.57
Female	13	35.1	11	28.9			
Comfort with Computers							
Very Uncomfortable	2	5.4	1	2.6			
Uncomfortable	5	13.5	7	18.4			
Uncertain	9	24.3	9	23.7	4	7.12	0.13
Comfortable	9	24.3	17	44.7			
Very Comfortable	12	32.4	4	10.5			
Previous Statistics Experience							
None	2	5.4	2	5.3			
Only a Little	5	13.5	2	5.3			
Some	10	27.0	7	18.4	4	3.35	0.50
A Considerable Amount	9	24.3	15	39.5			
A Great Deal	11	29.7	12	31.6			

The results showed that the student samples were statistically indistinguishable regarding grade point average, age, gender, comfort with computers and previous statistics experience. The applet-based and the traditional groups then, were sufficiently similar to compare.

Research Question I

Is there any statistically significant difference in the performance of students taught by Java applet-based instruction compared with those taught by traditional classroom instruction?

4.3 OVERALL PERFORMANCE AND PERFORMANCE WITHIN GROUP

A series of paired-samples *t*-tests were conducted to examine the question of whether students improved after completing the course, beginning with an analysis of the overall sample. Results are reported in Table 8. The average score on the pre-test examination was 60.40 $(\text{s.d.} = 8.09)$ while the mean score on the post-test was 87.40 $(\text{s.d.} = 4.82)$. The analysis indicated that the difference between the two scores was statistically significant in the expected direction, $t(74) = -40.51$, $p = 0.00$. That is, the overall group improved after receiving instruction. In addition, it was worth noting that in no instance did a participating student's score decrease, which suggests that all of the students benefited from their respective courses.

Table 8: *Comparison of Pre-test and Post-test Performance of All Participating Students*

Exam	Overall		*df*	*t*	*p*
	Mean	*s.d.*			
Pre-test	60.40	8.09	74	−40.51	0.00
Post-test	87.40	4.82			

Further analyses separate the participants in the applet-based instruction group from those who attended the traditional instruction group. Results are reported in Table 9 and Table 10. The average pre-test score for the applet-based group was 58.62 $(\text{s.d.} = 8.44)$ and the average score on the post-test was 88.14 $(\text{s.d.} = 5.12)$. The *t*-test indicated that the group improved significantly on the post-test, $t(36) = -36.45$, $p = 0.00$. The average pre-test score for the traditional group was 62.13 $(\text{s.d.} = 7.44)$, and the average score on the post-test was 86.68 $(\text{s.d.} = 4.46)$. As expected, the difference between the pre-test and the post-test was significant, $t(37) = -27.37$, $p = 0.00$.

Table 9: *Comparison of Pre-test and Post-test Performance of Students Enrolled in the Java Applet-based Instruction Group*

Exam	Applet-based		df	t	p
	Mean	*s.d.*			
Pre-test	58.62	8.44	36	−36.45	0.00
Post-test	88.14	5.12			

Table 10: *Comparison of Pre-test and Post-test Performance of Students Enrolled in the Traditional Instruction Group*

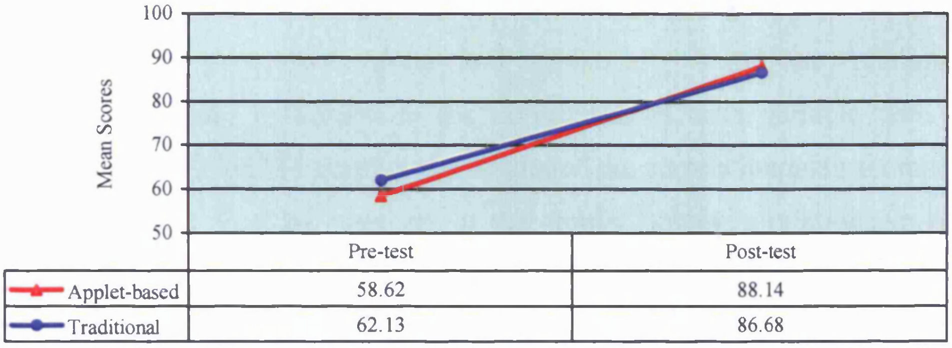
Exam	Traditional		df	t	p
	Mean	*s.d.*			
Pre-test	62.13	7.44	37	−27.37	0.00
Post-test	86.68	4.46			

4.4 PERFORMANCE BETWEEN GROUPS

One of the primary aims of this study is to enhance student learning. Pre-test and post-test scores are the primary measures of student learning.

As displayed on Figure 2, on the pre-test the applet-based instruction group had a mean of 58.62 with a standard deviation of 8.44. The traditional instruction group had a mean of 62.13 with a standard deviation of 7.44. On the post-test, the applet-based instruction group had a mean of 88.14 with a standard deviation of 5.12. The traditional instruction group had a mean of 86.68 with a standard deviation of 4.46.

Figure 2: *Testing Results for Applet-Based and Traditional Instructional Groups*



For each examination, the instructor used independent-sample t-tests to compare examination scores for the two groups. The means appears in Table 11. Scores on pre-test showed that the traditional instruction group $(M = 62.13)$ performed slightly, although not significantly, better than the applet-based instruction group $(M = 58.62)$, $t(73) = -1.91$, $p = 0.06$. Scores on the post-test were similar for the applet-based instruction group $(M = 88.14)$ and traditional instruction group $(M = 86.68)$, $t(73) = 1.31$, $p = 0.19$.

Table 11: *Comparison of Pre-test and Post-test Performance of Students Enrolled in an Undergraduate Statistics Course by Method of Instructional Delivery*

Exam	Applet-based		Traditional		*df*	*t*	*p*
	Mean	*s.d.*	*Mean*	*s.d.*			
Pre-test	58.62	8.44	62.13	7.44	73	−1.91	0.06
Post-test	88.14	5.12	86.68	4.46	73	1.31	0.19

4.5 RELATIONSHIPS BETWEEN VARIABLES

Individual Pearson Product-Moment Correlations were conducted to determine which variables possessed strong and statistically significant relationships. This procedure was done to determine the correlation of each variable with every other variable. Tables 12 and 13 display the results of the correlation analysis in the form of a correlation matrix. Positive numbers in the matrix indicate a relationship where as one variable increases, the related variable also increases. Negative numbers indicate an inverse of this relationship. The larger the number (in terms of absolute value) is, the stronger the relationship. Asterisks indicate whether the relationship was statistically significant given the null hypothesis that no relationship exists between the two variables in the population.

Table 12: *Correlation Matrix for Post-test Score, Pre-test Score, and Background Characteristics of Participants (Java Applet-Based Instruction Group)*

Variable	1	2	3	4	5	6	7
1. Post-test Score	--	0.85*	0.35	-0.08	-0.27	0.42	0.06
2. Pre-test Score	0.85*	--	0.40	-0.11	-0.14	0.33	-0.02
3. GPA	0.35	0.40	--	-0.08	-0.05	-0.04	-0.08
4. Age	-0.09	-0.11	-0.08	--	-0.18	0.14	0.27
5. Gender	-0.27	-0.14	-0.05	-0.18	--	-0.02	-0.08
6. Comfort with Computers	0.42	0.33	-0.04	0.14	-0.02	--	-0.12
7. Previous Statistics Experience	0.06	-0.02	-0.08	0.27	-0.08	-0.12	--

Table 13: *Correlation Matrix for Post-test Score, Pre-test Score, and Background Characteristics of Participants (Traditional Instruction Group)*

Variable	1	2	3	4	5	6	7
1. Post-test Score	--	0.76*	0.27	0.09	-0.11	0.14	0.11
2. Pre-test Score	0.76*	--	0.30	0.11	-0.07	0.13	0.16
3. GPA	0.27	0.30	--	0.13	-0.18	-0.11	-0.01
4. Age	0.09	0.11	0.13	--	-0.06	0.17	-0.01
5. Gender	-0.11	-0.07	-0.18	-0.06	--	-0.04	0.08
6. Comfort with Computers	0.14	0.13	-0.11	0.17	-0.04	--	0.13
7. Previous Statistics Experience	0.11	0.16	-0.01	-0.01	0.08	0.13	--

4.6 ANALYSIS OF COVARIANCE (ANCOVA) RESULTS

The analysis of covariance (ANCOVA) is one of the most complicated of the standard statistical methods. It is complicated because it involves combined employment of the concepts of analysis of variance (ANOVA) and regression analysis. The ANCOVA approach was utilized in the data analysis because it provides greater statistical power (Glass and Hopkins, 1984), and is beneficial in this study since the sample size was limited by class enrollments in the two study groups. Additionally, the ANCOVA approach was also useful in this study as it can significantly reduce within-group or error variance (Stevens, 1992).

An analysis of covariance was conducted to evaluate the effectiveness of the two methods of instruction. The independent variable was the method of instruction with two levels: the Java applet-base instructional method and traditional instructional method. The covariate was the pre-test taken before the lecture series began. The dependent variable was the post-test taken after completion of the lecture series. Differences in the post-test scores may be attributable not only to differences between the methods of instruction but also to initial differences in the pre-test scores. To control for any pre-existing differences between the experimental and control groups, the effect of the covariate (pre-test scores) has to be eliminated from the post-test scores by using the regression method. After covarying the pre-test scores, it is possible to test whether there was a significant difference among the group means.

Assumptions of ANCOVA

Since the ANCOVA technique involves features of both the analysis of variance (ANOVA) and regression, so assumptions for both were tested.

Assumptions of ANOVA

Normality and homoscedasticity (i.e., homogeneity of variance) across all groups were verified using the Kolmogorov-Smirnov test (Lilliefors, 1967) using Lilliefors *p*-values and Levene's Test for Equality of Variances (Levene, 1960), respectively.

The assumption of normality

The normality assumption is that the observations from each group must be randomly selected from a normal, or approximately normal, population. Using the Kolmogorov-Snirnov test, *p*-values of 0.35 (Java-applet based instruction) and 0.26 (Traditional instruction), were found, so there was no evidence to reject the null hypothesis the data were from a normal distribution.

The assumption of homogeneity of variance

The homogeneity of variance assumption is that the variance within each of the groups is equal. The *p*-value for Levene's test is 0.12, so the null hypothesis of equality of variances was accepted.

Assumptions of Regression

Prior to using ANCOVA, assumptions of homogeneous regression coefficients and linearity between the dependent variable (post-test) and the covariate (pre-test) were examined.

The assumption of homogeneity of regression coefficients

The homogeneous regression coefficients assumption is that the regression coefficients for each of the instructional group in the independent variables(s) should be the same, that is, the slopes of the regression lines are the same for each group.

Table 14: *Homogeneity of Within Regression Summary Table*

Source	*SS*	*d.f.*	*MS*	*F*	*p*
Group	3.96	1	3.96	0.42	0.52
Pre-test (Covariate)	957.63	1	957.63	101.99	0.00
Group * Pre-test	13.87	1	13.87	1.48	0.23
Error	666.63	71	9.39		
Total	1716.00	74			

The analysis of variance output is shown in Table 14. The only effect of interest is the interaction between the independent variable (Group) and the covariate (Pre-test). The interaction is not significant, $F(1,71)=1.48, p=0.23>0.05$. The slope in the experimental group (Java applet-based instruction group) is not significantly different from the slope in the control group (Traditional instruction group).

The assumption of linearity

The linearity assumption is that a linear relationship exists between the covariate and the dependent variable. Tables 15 and 16 contain the Pearson correlations displaying the linearity of the relationships between the covariate and the dependent variable contained in the correlation matrix.

Table 15: *Pearson Correlation (Java Applet-Based Instruction Group)*

Variable	Post-test Score	Pre-test Score
Post-test Score	1	0.85
Pre-test Score	0.85	1

Table 16: *Pearson Correlation (Traditional Instruction Group)*

Variable	Post-test Score	Pre-test Score
Post-test Score	1	0.76
Pre-test Score	0.76	1

For each instructional group, the linear relationship is well-defined.

The assumptions required for ANCOVA were well met. A one-way ANCOVA using general linear model (GLM) was then used to analyze the data.

Running the ANCOVA

The unadjusted or raw means are shown in Table 17. The lecture group's pre-test $(M = 62.13)$ was slightly (but not significantly) higher than the pre-test of the Java applet-based group $(M = 58.62)$. Further analysis using an ANCOVA was conducted to re-evaluate the post-test means, adjusting for meaningful, although not statistically significant, differences in the covariate (the pre-test).

The adjusted means are also shown in Table 17. The adjusted means are the predicted post-test scores at the overall mean of the pre-test scores. That is, the adjusted means are the post-test means that one would achieve if all of the groups in the study had the same pre-test means. Following the adjustment for the pre-test as covariate, the adjusted mean post-test scores was 88.96 for the applet-based instruction group and 85.88 for the traditional instruction group, suggesting that students in the applet-based instruction group scored higher on the adjusted post-test than the traditional instruction group.

Table 17: *Unadjusted and Adjusted Means*

Group	Pre-test		Post-test		
	Mean	*s.d.*	*Mean*	*s.d.*	*Adjusted Mean*
Applet-based	58.62	8.44	88.14	5.12	88.96
Traditional	62.13	7.44	86.68	4.46	85.88

The scores for both tests were subjected to analysis of covariance (ANCOVA). Table 18 presents the ANCOVA summary table. Results of the analysis showed a significant difference between the two groups for the intervention effect, $F(1,72) = 17.93,\ p = 0.00$. Thus, the null hypothesis of no significant difference among the adjusted means on the dependent variable was rejected. Overall, the ANCOVA results reveal that students who attended the Java applet-based instruction group scored significantly higher than the ones who attended the traditional instruction group. In other words, the Java applet-based instruction format was significantly more effective than the traditional instruction format for improving students' achievements.

Table 18: *Results of ANCOVA on Students' Post-test Scores with Pre-test Scores as the Covariate*

Source	*SS*	*d.f.*	*MS*	*F*	*p*
Pre-test (Covariate)	996.04	1	996.04	105.39	0.00
Group	169.50	1	169.50	17.93	0.00
Error	680.50	72	9.45		
Total	1716.00	74			

4.7 MULTIPLE REGRESSION ANALYSIS RESULTS

Multiple regression analysis was conducted in this study since it is very suitable for analyzing the collective and separate effects of two or more independents on a dependent variable.

The following multiple regression model was used to test student performance as measured by the dependent variable: post-test score.

$$\begin{aligned} \mathit{Post\text{-}test} &= \beta_0 + \beta_1 \cdot \mathit{Applet} + \beta_2 \cdot \mathit{Pre\text{-}test} + \beta_3 \cdot \mathit{GPA} + \beta_4 \cdot \mathit{Age} + \beta_5 \cdot \mathit{Gender} \\ &\quad + \beta_6 \cdot \mathit{Comfort} + \beta_7 \cdot \mathit{Experience} + \varepsilon \end{aligned}$$

where

Post-test	=	post-test score
Applet	=	Java applet variable (0 = lecture group, 1 = Java applet group)
Pre-test	=	pre-test score
GPA	=	prior grade point average of student
Age	=	age of student
Gender	=	gender (1 = male, 2 = female)
Comfort	=	comfort with computers (5-point scale with 1 = very uncomfortable, and 5 = very uncomfortable)
Experience	=	previous statistics experience (5-point scale with 1 = none, and 5 = a great deal)
β_0	=	the regression constant
β_j	=	the regression coefficient for variable x_j : $j = 1, 2, ..., k$
ε	=	the random error term

Multiple Regression Analysis for Student Performance on Post-test (including all variables)

Individual significance tests for each regression coefficient by using a t test are displayed with the results of the multiple regression in Table 19.

Table 19: *Significance Tests of the Regression Coefficients*

Independent Variable	Coefficient	t	p
Constant	60.45	9.49	0.00
Applet	2.95	4.01	0.00
Pre-test	0.42	8.35	0.00
GPA	0.66	0.86	0.39
Age	−0.17	−0.62	0.54
Gender	−1.16	−1.51	0.14
Comfort	0.62	2.82	0.04
Experience	0.22	0.71	0.48

The multiple regression equation was

$$\begin{aligned} \textit{Post-test} &= 60.45 + 2.95 \times \textit{Applet} + 0.42 \times \textit{Pre-test} + 0.66 \times \textit{GPA} - 0.17 \times \textit{Age} \\ &\quad -1.16 \times \textit{Gender} + 0.62 \times \textit{Comfort} + 0.22 \times \textit{Experience} \end{aligned}$$

The t-statistics associated with each regression coefficient was used to test the null hypothesis that a regression coefficient is equal to zero, i.e., that particular independent variable has no effect on the dependent variable. GPA, age, gender, and experience were found to be non-significant for measure of performance because the t ratio for GPA was 0.86 with an associated p-value of 0.39, the t ratio for age was −0.62 with an associated p-value of 0.54, the t ratio for gender was −1.51 with an associated p-value of 0.14, and the t ratio for experience was 0.71 with an associated p-value of 0.48. Neither p-value was less than 0.05. Thus, the null hypothesis was accepted that each of these four independent variables had no effect on the dependent variable (post-test). A common rule of thumb is to drop all variables not significant at the 0.05 level from the analysis.

Some additional multiple regression statistics are presented in Table 20.

Table 20: *Summary Output*

Regression Statistics	
Multiple R	0.80
R Square	0.64
Adjusted R Square	0.60
Standard Error	3.05
Observations	75

The coefficient of multiple correlation (or multiple R), $R = 0.80$, indicated a strong linear relationship between the dependent variable and the set of independent variables.

The R square (coefficient of multiple determination), $R^2 = 0.64 \text{ or } 64\%$, indicated that approximately 64% of the total variation in post-test score was explained by the multiple regression model; 36% was not explained by the multiple regression model.

A comparison of $R^2\,(0.64)$ with the adjusted $R^2\,(0.60)$ showed that the adjusted R^2 reduces the overall proportion of variation of the post-test score accounted for the multiple regression model by a factor of 0.04, or 4%. This indicated that the value of R^2 was not inflated.

The standard error of the estimate, $S_e = 3.05$, indicated that approximately 68% of the errors of prediction were within ± 3.05.

The F test of overall significance of the multiple regression model was performed and appeared as an analysis of variance (ANOVA) table, Table 21.

Table 21: *Significance Test of the Multiple Regression Model*

Source	*SS*	*d.f.*	*MS*	*F*	*p*
Regression	1093.66	7	156.24	16.82	0.00
Error	622.34	67	9.29		
Total	1716.00	74			

The value of F was 16.82, with a p-value of 0.00, which was significant at $\alpha = 0.05$. On the basis of this information, the null hypothesis would be rejected for the overall test of significance. There is evidence to conclude that the multiple regression model has significant predictability for the dependent variable (post-test).

Multiple Regression Analysis for Student Performance on Post-test (only including significant variables)

After excluding the non-significant variables (GPA, age, gender, and experience), a separate multiple regression was ran yielding the following multiple regression results.

Individual significance tests for each regression coefficient by using a t test are displayed with the results of the multiple regression in Table 22.

Table 22: *Significance Tests of the Regression Coefficients*

Independent Variable	Coefficient	*t*	*p*
Constant	57.14	20.01	0.00
Applet	2.90	3.98	0.00
Pre-test	0.45	9.68	0.00
Comfort	0.53	2.61	0.04

The multiple regression equation was

$$\textit{Post-test} = 57.14 + 2.90 \times \textit{Applet} + 0.45 \times \textit{Pre-test} + 0.53 \times \textit{Comfort}$$

Some additional multiple regression statistics are presented in Table 23.

Table 23: *Summary Output*

Regression Statistics	
Multiple R	0.78
R Square	0.62
Adjusted R Square	0.60
Standard Error	3.04
Observations	75

The coefficient of multiple correlation (or multiple R), $R = 0.78$, indicated a strong linear relationship between the dependent variable and the set of independent variables.

The R square (coefficient of multiple determination), $R^2 = 0.62 \text{ or } 62\%$, indicated that approximately 62% of the total variation in post-test score was explained by the multiple regression model; 38% was not explained by the multiple regression model.

A comparison of $R^2\left(0.62\right)$ with the adjusted $R^2\left(0.60\right)$ showed that the adjusted R^2 reduces the overall proportion of variation of the post-test score accounted for the multiple regression model by a factor of 0.02, or 2%. This indicated that the value of R^2 was not inflated.

The standard error of the estimate, $S_e = 3.04$, indicated that approximately 68% of the errors of prediction were within ± 3.04.

The F test of overall significance of the multiple regression model was performed and appeared as an analysis of variance (ANOVA) table, Table 24.

Table 24: *Significance Test of the Multiple Regression Model*

Source	*SS*	*d.f.*	*MS*	*F*	*p*
Regression	1059.43	3	353.14	38.19	0.00
Error	656.57	71	9.25		
Total	1716.00	74			

The value of F was 38.19, with a p-value of 0.00, which was significant at $\alpha = 0.05$. On the basis of this information, the null hypothesis would be rejected for the overall test of significance. There is evidence to suggest that the multiple regression model has significant predictability for the dependent variable (post-test).

When $Applet = 1$ (Java applet group), the multiple regression equation became

$$\begin{aligned} \textit{Post-test} &= 57.14 + 2.90 \times (1) + 0.45 \times \textit{Pre-test} + 0.53 \times \textit{Comfort} \\ &= 60.04 + 0.45 \times \textit{Pre-test} + 0.53 \times \textit{Comfort} \end{aligned}$$

When $Applet = 0$ (lecture group), the multiple regression equation became

$$\begin{aligned} \textit{Post-test} &= 57.14 + 2.90 \times (0) + 0.45 \times \textit{Pre-test} + 0.53 \times \textit{Comfort} \\ &= 57.14 + 0.45 \times \textit{Pre-test} + 0.53 \times \textit{Comfort} \end{aligned}$$

Multiple regression analysis signified that, on average, students in the Java applet-based group performed better on the post-test and had higher post-test scores in the course. Thus, the use of Java applets in statistics courses had a positive influence on student performance.

Research Question II

Is there any statistically significant difference in student attitude, before and after course completion, for students taught by Java applet-based instruction?

4.8 STUDENT ATTITUDE

Another important aspect is the attitudes students bring to the process. The degree to which the participants felt positively about Java applet-based instruction was measured in a series of 20 attitudinal questions on a self-administered questionnaire. The survey, designed specifically for the Java applet-based instruction group, was administered before the instruction commenced and once again after the course was completed. The objective of conducting the attitudinal survey was to determine if there was any change in student attitude during the length of the course.

The attitudinal questions employed a five-item Likert-type scale with possible responses ranging from a score of 1, which indicated the least positive response, to 5, the most positive response. The items were then combined into a single index, which was averaged across the items in order to maintain the same $1 \rightarrow 5$ response scale. Note that Likert scales are ordinal but very commonly used with interval procedures, provided the scale has at least 5 categories (Jaccard and Wan, 1996).

Prior to going through the course, students were generally positive about the process $\left(M = 3.68,\ \text{s.d.} = 0.75\right)$. Their outlook was even more positive after having completed the course $\left(M = 4.19,\ \text{s.d.} = 0.78\right)$. A paired-sample t-test indicated that the change in attitude was statistically significant, $t(36) = -2.16$, $p = 0.04$. Results are reported in Table 25. Bivariate tests revealed that post-instruction attitudes were not related to GPA, age, gender, the degree of comfort with computers, or previous statistics experience. The results support the view that students' attitude was influenced by the applet-based environment and was not due to student demographic characteristics.

Table 25: *Comparison of Pre- and Post-Instruction Attitudinal Survey Results of Students Enrolled in the Java Applet-based Instruction Group*

Attitudinal Survey	Applet-based		*df*	*t*	*p*
	Mean	*s.d.*			
Pre-Instruction	3.68	0.75	36	−2.16	0.04
Post-Instruction	4.19	0.78			

Research Question III

Is there any statistically significant difference in student satisfaction for students taught by Java applet-based instruction compared with those taught by traditional classroom instruction?

4.9 STUDENT SATISFACTION

Students in both Java applet-based and traditional groups completed the Course and Instructor Evaluation Form at the end of classes. All of the students in both groups were present and completed the evaluation instrument. The objective of conducting the end-of semester evaluation survey was to compare student satisfaction between Java applet-based and traditional groups.

Students rated the course and the instructor on a 5-point Likert scale rating from 1 (strongly disagree) through 5 (strongly agree) on eighteen dimensions. Recall that interval techniques can be used with ordinal Likert scales, provided the scale has at least 5 categories (Jaccard and Wan, 1996). The group means are reported in Table 26.

Table 26: *Student Satisfaction by Survey Question*

Question	Applet-based		Traditional		*df*	*t*	*p*
	Mean	*s.d.*	*Mean*	*s.d.*			
1. The instructor was well prepared and organized.	4.27	0.73	3.79	0.74	73	2.83	0.01
2. The course was well organized and designed.	4.32	0.75	3.76	0.75	73	3.24	0.00
3. Students' range of knowledge and skills of statistics was greatly enhanced within this course.	4.32	0.75	3.79	0.78	73	3.04	0.00
4. Students were informed of progress in meeting course goals.	4.22	0.79	3.74	0.83	73	2.57	0.01
5. The instructor was effective.	4.30	0.78	3.71	0.84	73	3.15	0.00
6. Course materials were relevant and meaningful.	4.27	0.77	3.74	0.76	73	3.02	0.00
7. Presentation of the topic was useful.	4.22	0.79	3.82	0.77	73	2.23	0.03
8. Clear explanation of statistical concepts.	4.24	0.76	3.76	0.75	73	2.75	0.01
9. The learning process was facilitated by the methodology and tools used in this course.	4.30	0.78	3.76	0.79	73	2.96	0.00
10. The instructor displayed good communication skills.	4.16	0.76	3.66	0.85	73	2.70	0.01
11. The instructor explained well.	4.14	0.75	3.71	0.87	73	2.26	0.03
12. The instructor gave me sufficient time to understand the work I had to learn.	4.22	0.75	3.79	0.74	73	2.48	0.02

13. The instructor was empathetic and seemed to understand difficulties I might be having with my work.	4.35	0.75	3.63	0.79	73	4.05	0.00
14. The instructor provided helpful feedback on how I was doing.	4.19	0.78	3.82	0.77	73	2.10	0.04
15. The course stressed techniques that stimulated my interest in the content being covered and the instructor welcomed questions on these.	4.19	0.81	3.66	0.91	73	2.67	0.01
16. The instructor aroused my interest to learn other topics in statistics.	4.16	0.80	3.61	0.92	73	2.80	0.01
17. The instructor has confidence in his knowledge of statistics.	4.27	0.77	3.68	0.77	73	3.29	0.00
18. The instructor deserved recommendation based on my knowledge gained in this course.	4.16	0.83	3.63	0.91	73	2.63	0.01

Overall, this statistics course has received a very positive evaluation. The student evaluation of teaching instrument was measured on a five-point Likert scale, with five being strongly agree. The lowest mean evaluation from any section was a 3.61, somewhere between "neutral" and "agree". As a group, students rated this course highly with a grand mean of 3.98.

The students in each of the two sections of the course were found to differ in their levels of satisfaction.

Independent-samples *t*-tests were calculated for each of the eighteen questions across each of the two sections. Alpha was established apriori at 0.05. Significant differences were found between the applet-based and traditional groups in every case with students in the traditional group agreeing less strongly. The findings are summarized in Table 26. Students' ratings provided additional evidence for the effectiveness of the applet-based group over the traditional group.

Research Question IV

What kind of opinions do the students express of interactive applets?

4.10 STUDENT OPINION

The sample of student comments were taken from the comments in response to the open-ended questions on the evaluation instrument and provide additional insight.

Open-ended Question (a)

Give important aspects of this course.

The responses were as follows:

Students from Applet-Based Group

"Improved visualization of statistical concepts and processes."
"Excellent and enjoyable graphics."
"The use of the internet to interact, study questions, notes, etc. on-line were very useful."
"Easy to use, clear and useful graphics."
"Eye-catching illustrations and easy to navigate."
"It was really cool! You got to experience with it."
"It is a good way to learn because if you don't understand you can go back and re-read the information."
"The course made a hell of a difference."
"It was clear and well set out."
"Applets could present picture proofs. With animation it was possible to present picture proofs that one could not do without a computer."
"Very good. Less of a focus on computations. This frees us to spend more time focusing on and understanding the concepts."
"Yes, it was cool."
"Hands-on involvement vastly accelerates the rate of learning."
"Learning statistical concept visually was good."

"The use of the interactive Java applet made the process of learning more enjoyable."

"Navigation buttons were user friendly."

"It is easier to take in information in this form."

"The applets have been created for the purpose of teaching statistics using interactive graphics in the classroom."

"This style of interactive lecture was beneficial to learning."

"I think teaching and learning are very possible via this medium."

"The use of the interactive Java applet increased the value of the lesson."

"Applets help visualize concepts of statistics."

"I like and understand things better when I can get hands-on activities."

"It did increase my understanding of statistics and kept my interest more than lecture and note taking."

"Applets helped me learn objectives and helped me understand what was being taught better."

"Applets increased my understanding of difficult abstract statistical concepts."

"I think it's going to be a great teaching/learning tool because of the versatility it will offer to teachers and students."

" It helped support learning and it made it more fun."

"The applets definitely enhanced my learning and conceptualization of statistics and assisted me in visualizing statistical concepts."

"I know that applets helped me learn the objectives because they were presented very well and were also interesting."

"Statistics without applets would not be as much fun."

"Applet-based classes provide possibilities and measure up to traditional classes."

"Great visuals."

"Applets made me want to explore and experiment."

"Using interactive simulation in the classroom was very helpful."

"It was better learning – the applets made things clearer and easier to understand. Statistical learning is much easier when you have a picture to show you what you are doing."

"Good looking demonstrations."

Students from Traditional Group

> *"The opportunity to take advantage of a variety of learning strategies – lectures, class notes, study questions and follow-up questions – were all useful."*
> *"The instructor was good at clearly explaining new concepts."*
> *"The overhead projector complemented the preprinted notes."*
> *"Well-organized course."*
> *"The instructor motivated me to do my best work."*
> *"The instructor appeared enthusiastic about the material being presented."*

Open-ended Question (b)

Provide constructive and actionable suggestions for course improvement.

The responses were as follows:

Students from Applet-Based Group

> *"No suggestions. Excellent job."*
> *"None. Great class."*
> *"Create your own applets or look for more ready-made applets."*
> *"Some topics become less abstract with the use of interactive Java applets."*
> *"Ease of use with clear instructions, not limited by technical resources, and does not require too much technical support."*
> *"There should be more interactive demonstrations in the classroom."*
> *"Statistics educators should encourage students to use technology in their learning of statistics."*
> *"The applets should provide information that is interesting and relevant to the student."*
> *"Use more interactive applets to illustrate statistical concepts."*

Students from Traditional Group

> *"Provide more help for the math parts of the course."*
> *"The theory behind the variation between groups and the variation within group is hard to grasp."*
> *"ANOVA is a hard topic to understand."*
> *"Concept of standard deviation is difficult."*
> *"Establish a clear link between statistics and its use in the real world."*

Very positive student responses were elicited using Java applets in teaching and learning of statistics. The above comments noted the students have reinforced notions of statistical concepts, improved visual perception as well as comprehension of abstract concepts. According to this study, students believed that applet-based learning was the most appropriate teaching approach because applets could enhance educational material with dynamic graphics, applications that were responsive to student choices, and provided interactivity to engage students in active and discovery learning. The interactivity inherent in the applets allowed students to interact with the statistical concept being studied, to explore how the underlying principles could be derived, to make errors, and seek their own solutions. The applet-based instruction has created a constructivist learning environment in which students were more actively engaged in interactive and collaborative activities that encourage and facilitate learning by visualization and experimentation. Students learned better and more when they were encouraged to ask their own questions, carry out their own experiments, share their own knowledge, discover the information for themselves, make their own analogies, and draw their own conclusions; rather than being told what to learn in a traditional classroom setting.

Research Question V

Why should statistics instructors use applets in teaching? What kinds of advantages and disadvantages appear in learning through interactive applets?

4.11 WHY APPLETS

Instead of focusing on the complexities of trying to get statistical concepts right on the board, instructors can concentrate on explaining abstract concepts, building models, and also facilitating problem solving in an interactive learning environment. It is refreshing to move away from the endless diagrams and static approaches to showing how these concepts work.

It is good that applets are not tied to a specific operating system or PC, students can manipulate the applets as long as they have access to the Internet/Intranet, and a Java-compliant Web browser such as Netscape Navigator or Microsoft Internet Explorer. Students can access and play with the same applets, over and over again, demonstrated during class time.

Course texts, PowerPoint slides, transparencies, and blackboard drawings are all useful teaching aids, but they are not as dynamic as applets. The dynamic nature of applets allows instructors to show what happens instantaneously as a parameter changes, rather than to discuss what would happen. The Graphical User Interface (GUI) of applets can be easily customized specifically for one's needs. The users can modify parameters and/or variables and see the results immediately. The dynamic interactivity significantly assists students to comprehend statistical concepts and meet the learning objectives of the course.

Applets can help students to visually reinforce abstract concepts covered in class during their out-of-class study time. More importantly, this provides an opportunity to stimulate students exploration and self-discovery of related topics on their own, and consequently this may foster a deeper learning based on exploration and discovery, and also train students in learning to learn.

4.12 ADVANTAGES AND DISADVANTAGES OF INTERACTIVE APPLETS

There are a number of advantages and disadvantages of using applets as an interactive learning environment. The advantage of using applets is that they can give students a sense of how the dynamics of statistics work, by working with the parameters and values of the specific variables. The dynamic features of applets open up a new perspective of solving statistical problems. The applets are especially useful for creating visual presentation of abstract statistical concepts, which cannot easily be visualized through static pictures drawn with chalk or markers on a blackboard or a whiteboard. The applets can be run on any PC, Mac, UNIX machines or even mainframes. Nothing is perfect, and applets also have their own disadvantages. The applet approach of learning is a new kind of representation that might take some time for students to get used to. The learning curve for this type of learning can also be potentially quite time-consuming and as a result may impede learning as well.

Research Question VI

According to Khan's WBL framework, does the Java applet-based instructional approach create a meaningful learning experience?

4.13 COURSE EVALUATION

Due to the breadth and comprehensiveness of Khan's WBL framework, which includes eight dimensions and around sixty sub-components, a simplified strategy was selected to evaluate the Java applet-based course. By mapping Khan's WBL framework to the Java applet-based course, it was found that specific strengths and weaknesses of the course can be matched with many of the framework's components. Avoiding unnecessary complexity, only the micro-end dimensions will be under discussion.

Pedagogical

In the Pedagogical Dimension, the students possessed the prior technological knowledge or skills needed to start the applet-based course. The instructional goals and objectives of the course were relevant to the students. The course goals were approved by appropriate officials within the institution.

Next, each of the applets included in the course were carefully chosen and described in the syllabus then mapped to the specific concepts to be taught. Not all the topics covered in the course were illustrated by Java applets, only topics which posed special difficulties in comprehension or required a much-needed illustration were chosen. The applets successfully complemented the traditional in-class instructional approaches with information which was difficult to convey in a conventional manner.

It was also critical to realize that Java applets could integrate easily with a wide variety of media formats and languages including VRML and JavaScript which made them ideal for quickly being deployed in a variety of teaching scenarios. HTML was not suitable for this level of customization as it could not support the ability to create interactive learning environments.

Interface Design

With respect to the Interface Design Dimension, any applet-based course would be a welcome change from the manually-based workflows in other classes. It was possible to create clear, complete and concise definitions within a Java applet, making navigation easily accomplished.

Furthermore, the use of applets stimulated the students to experiment and work with the concepts rather than just rely on a "laid back" learning strategy. The Java applets were designed to fulfill the needs of having an easy-to-navigate graphical user interface (GUI) in addition to the ability to simplify the complex concepts in statistics through visualization.

Speed was another critical aspect of the development of Java applets, as network speeds could significant impact on their performance. In conjunction with this key point was the need to be selective in which information was provided to students in the context of the Java applets themselves. Too much information and the Java applet would slow down and not work efficiently over an Internet connection or on an Intranet; not enough information and the example would be meaningless. Clearly a balance between design simplicity and sophistication relative to the amount of data used was critical.

Evaluation

For the Evaluation Dimension, the assessment has provided students with the opportunity to demonstrate what they had learned in the course. The fact that traditional methods of assessing performance in class could be easily replaced with more interactive tests would change this dimension of the Khan framework significantly over time. In fact, the use of Java applets for testing would also improve the depth and insight that could be tested of complex concepts.

According to Khan's WBL framework, the applet-based instruction not only offers us the ability to be more efficient in delivering learning, but more effective.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter provides conclusions and recommendations for further research. Section 5.1 contains a general discussion of the findings. Limitations of this study are pointed out in Section 5.2. Section 5.3 provides a summary of the results from this thesis. In Section 5.4 discusses some implications of the research conducted. Section 5.5 contains ideas about possible future research.

5.1 DISCUSSION

A common catchphrase today is "thinking outside the box," and this concept is particularly applicable when it comes to the paradigm shift in teaching and learning that is taking place today. The transition from an objectivist to constructivist learning environment has introduced some new opportunities for educators as well as some significant challenges in developing interactive approaches to educational services delivery that satisfy learners' increasingly sophisticated expectations in on-line settings. The opportunities associated with the ongoing paradigm shift to student-centred learning are virtually limitless, but the challenges are also formidable and complex. Moreover, there has been insufficient time involved since the introduction of these methods to accurately determine how these constraints can best be addressed in some cases.

While best practices in the use of these rapidly evolving technologies and their application to the on-line classroom continue to be identified and refined, students are increasingly going to expect the best of what is available in terms of virtual learning, and educators that are able to deliver the goods in this dynamic environment can reasonably be expected to achieve superior academic outcomes compared to their objectivist counterparts who continue to rely on stodgy lectures and rote memorization. This is not to say, of course, that objectivist educational approaches are inappropriate in every setting or that every student will benefit from a constructivist approach; however, taken together, the studies to date and empirical observations suggest that these trends are real and a paradigm shift in educational pedagogy (Barr and Tagg, 1995) has taken place within the past decade or so that carries some profound implications concerning how educational services will be delivered in the 21^{st} century classroom.

The application of learning statistics using Java applets may benefit students by empowering them to developing their own understanding of statistical concepts. Students will have the opportunity to learn by constructing their own ideas and knowledge from the interactive simulation experiences, with supportive direction from the instructor. By being actively involved in the learning process, students will become more independent learners and problem solvers.

Curricular development initiatives that focus on improving the convenience and interactivity of course offerings have been shown to improve student performance (Ng and Ma, 2002). Likewise, the growing body of evidence concerning interactivity suggests that this aspect of learning provides students and teachers alike with a wide range of benefits that can promote both academic outcomes as well as generate improved critical thinking skills among students. By engaging student interest and encouraging interactive involvement in course content and with other students, interactive approaches to the delivery of educational services represent a win-win teaching modality.

There are some constraints involved in developing and implementing effective interactive teaching approaches, though, that must be taken into account as well. Today, a generation of so-called "digital natives" enjoys a level of technological expertise that some older people do not possess – and may never possess. While it is reasonable to conclude that many students entering college today bring with them valuable computer skills that readily lend themselves to interactive learning, it is also reasonable to assume that some students will either not possess these skills or will not be as comfortable applying them in a self-directed fashion. Nevertheless, these trends are also clear and a growing number of students can reasonably be expected to enter tertiary educational institutions with computer skills and the expectation to use them to further their academic pursuits. Likewise, there will undoubtedly be substantive differences in the interactive expertise of administrators that will affect the integration of these learning tools in these institutions. However, it is also reasonable to conclude that as educators and administrators gain additional expertise in their use, the application of interactive learning modalities will become even more commonplace in the future.

The learner-interface interaction is probably the most challenging type of interaction (Hillman, Willis, and Gunawardena, 1994) because it is not required in the conventional classroom instruction. With applets, the visualization of abstract statistical concepts seems possible. Applets are not static in comparison with course texts, handouts, transparencies, and blackboards: applets are dynamic and interactive. They can respond to user input and thus provide the students with an interactive learning environment. Java applets can enhance educational materials with animations, applications that are responsive to student choices, and provide interactivity to engage students in active learning. The interactivity inherent in these applets allows a student to explore, to make errors, and seek their own solutions. In moving from an entirely teacher-centred to a student-centred approach, learning will be less dependent on the instructor delivering knowledge and more driven by students exploring, discovering, and constructing their own knowledge, which is in line with the constructivist learning approach (Jonassen, et al., 1995). As a result, students' understanding of the course content can further improve.

Although collaborative learning is not a new concept in classrooms, the underlying principles have assumed some new relevance in the emerging constructivist educational paradigm. People tend to learn more effectively and retain what they have learned for longer periods of time when they engage in collaborative learning approaches (Srinivas, n.d.). The introduction of computer-assisted and Internet-based teaching modalities has created some new opportunities for collaboration that do not exist in most traditional classrooms, and students are now able to communicate with their peers, teachers and course facilitators at the time and place of their choosing (Ocker & Yaverbaum, 2001). Indeed, this approach may be viewed as superior to the face-to-face small groups used by educators in the past to facilitate collaborative learning approaches because students are provided with time to consider the points being made by their cohorts and can formulate informed responses rather than knee-jerk reactions to new concepts and ideas. Collaborative and interactive learning approaches also provide educators and students alike with a number of benefits that make these techniques highly effective in a wide range of educational settings.

However, the paradigm shift in education and teaching to student-centred instruction has introduced some new challenges. These include ensuring that all students are comfortable with the format and that communication channels are seamless, that must be taken into account in order to ensure that these benefits are realized in substantive ways. In sum, the trends are clear and the paradigm shift has passed the point of no return. The classroom of the 21st century will be very different from that of a century ago, of course, and the manner in which teachers and students go about their respective roles in the teaching/learning process will undoubtedly become inextricably interconnected with the technology that supports them.

The traditional classroom-lecture teaching method is largely a one-way technology. It neither encourages active participation nor offers students an opportunity to learn collaboratively from one another. In the traditional classroom setting, students are expected to sit back passively, listen to the instructor to deliver his or her expert educational knowledge, and take notes in the classroom, and try to absorb what they see or hear. The number one rule is simply "Listen to your teacher and pay attention during the class" and if there is something that students do not understand, then ask the instructor for clarification. But most students prefer not to ask questions because they are timid, are embarrassed to ask questions in front of their classmates. There are hardly any interactions between the students, and rarely any opportunities for students to work together with their peers as a team in their learning process.

Contrary to the traditional method of learning, the applet-based learning creates a collaborative Web-based learning environment in which students will have the opportunity to interact with each other, share ideas and discussions during the in-class hands-on laboratory practice session when they manipulate the applets and explore the underlying statistical concepts. The applet-based (constructivist) classroom relies heavily on collaboration between students. Students learn about learning not only from themselves, but also from their peers. The student-peer collaboration fosters a deeper understanding of the subject matter and more importantly aids students in learning how to learn collaboratively. As a result, the overall learning experience will be a very rewarding and invaluable experience.

The findings from this study portray a number of issues. Pre-tests and post-tests of the students' knowledge demonstrated that an applet-based class may be more effective than a good lecture in fostering learning about core statistical concepts. An implication is that it would be possible to use applets to replace some of the in-class presentations, freeing some class time for class discussion or other teaching activities. The applet-based class provides some important advantages over the lecture format. The use of applets gives students substantial control over the learning process including the convenience of using these on-line tools at their convenience. Students found that the use of applets at the best times for their learning, from any location, using them at their own pace, greatly increased their learning potential. As students gain experience with applet-based classes, there may be even greater acceptance of the medium.

The applet-based teaching incorporated several techniques for enhancing student learning. These techniques included setting authentic challenges to student understanding, presenting students with multiple perspectives, promoting reflective thinking, and addressing students' common misconceptions. Setting a suitable learning challenge (Park and Hannafin, 1993), entails the use of an authentic problem, for students through materials that go beyond simple calculation and which involve statistical values. The use of applets also involve enhancing students' ability to recognize multiple perspectives (Mayer and Anderson, 1992) through problems that require not just calculation, but also interactive manipulation as well as interpretation. The development of students' reflective thinking (Hoffman and Ritchie, 1997) through questions that force them to stop at various points during a class and respond to questions about results can also be achieved. The use of applets can also help in identifying students' common statistical misconceptions of concepts and lead class discussions to allow for active confrontation of misconceptions (Garfield, 1995).

As demonstrated by the applet-based class, many important principles of good instruction can be incorporated into Web-based classes. Based on the encouraging results from this evaluation, it is obvious that interactive applet-based class can give an effective supplement, or even replacement for traditional classroom lectures. Since no users or instructors can be expected to make correct subjective comments regarding the effectiveness of educational software, so in order to have assurance, it is essential to perform evaluation (Jolicoeur and Berger, 1986).

5.2 LIMITATIONS OF THE STUDY

There are several limitations that need to be addressed with respect to this study. First and foremost, the sample for the evaluation study was relatively small which limits the scope for generalization. The small sample size also limits the statistical power of the study. That is, there is a higher chance of getting a Type II error; which means that it would be difficult to detect a difference if in fact, a true difference in achievement existed. Second, it is unclear whether students only learn more initially or if applet-based instruction leads to long-term (multiyear) retention of key statistical concepts. Third, this study involved only a single-institution. Finally, using interactive Java applets presentation in other sciences and in other disciplines would add to our understanding of using technology in education.

5.3 CONCLUSION

In summary, both applet-based and lecture teaching resulted in increased knowledge about statistics. What is fascinating about the study itself is that in not a single instance did a student's score decrease, which suggests that all of the students benefited from their respective courses.

The following paragraphs summarize the findings in this study and link them with the research questions.

The results of this study appear to have answered the research questions. Firstly, the performance of students differs significantly across the two modes of instruction. The findings of this study showed that the applet-based instruction group scored significantly higher on knowledge tests. These findings supported prior research (Agarwal and Day, 1998; Al-Jarf and Sado, 2002; Clark, 2003; Day, Raven, and Newman, 1998; Dutton, Dutton and Perry, 2001; Jordan, Smith, Dillon, Algozzine, Beattie, Spooner, and Fisher, 2004; McCreanor, 2000; Navarro and Shoemaker, 2000; Schutte, 1996; Yu and Yu, 2001): the performance of students in a Web-based course was better than the performance of students in the on-campus course.

Secondly, student attitude differs significantly before and after course completion, for students taught by Java applet-based instruction. Students were generally positive about applet-based instructional method, both before and after course completion. In fact, attitudes were significantly more positive after the course was finished. This supported some previous research (Day, Raven, and Newman, 1998; Despain, 1997; Dewhurst, Macleod, and Norris, 2000; Driver, 2002; Felix, 2001; Goolkasian, 1989; Hughes and Hagie, 2005; Karuppan and Karuppan, 1999; Kulik, 1994; Spivey, 1983; Summary and Summary, 1998; Ware and Chastain, 1989) that the utilization of the WWW improves student attitude toward the topic.

Thirdly, student satisfaction differs significantly across the two modes of instruction. The applet-based instruction group rated statements significantly higher than did the lecture group. These results were in coherence with the results of the study by Enockson (1997) and Liu (2005) where students have a higher ratings of satisfaction in Web-based courses than their traditional counterpart.

Fourthly, the students have been very positive about learning by using interactive applets. The applet-based instruction has created a constructivist environment which allows higher levels of interaction between students and interface, and also collaboration between student peers.

Fifthly, the highly interactive/dynamic/portability nature of Java makes it an ideal tool for the development of applets for creating interactive learning environment. But one significant drawback in the development of applets is the advanced level of experience in programming and expertise required in developing, authoring and packaging for these applications. Clearly, there is a need for greater education for instructors to motivate them to create these applets.

Lastly, in line with Khan's WBL framework, focus was put on the three micro-end dimensions (Pedagogical, Interface Design and Evaluation), the Java applet-based instructional approach has created a meaningful learning experience. Applets provide immediate visualization of what is going on so students can understand (constructivist approach) ... rather than just rote memorisation (objectivist approach).

The educational contributions of this study are fivefold. First, the results of this study emphasise the potential of applet-based class for delivering statistics courses. Second, the students from the applet-based group learnt some technology skills from which they will benefit later in advanced statistics courses and the workplace. Third, graphical illustrations and the use of interactive, real-time simulations can greatly enhance a student's understanding of statistical concepts and methods (Tanis, 1987). Graphical illustrations effectively convey important ideas of statistical concepts, and interactive, real-time simulations take the drudgery out of statistical calculations. Fourth, Java applets can help create an interactive environment of "learning by doing". Beyond their ability to better convey certain statistical concepts, the applets can enhance students' interest and motivation, and encourage students to participate more actively in the class, and consequently deepen their understanding of the course content. Finally, it is apparent from the results that educational technology is very useful to student learning.

The applet-based class shows that Web-based materials can include many important principles of constructivist education. Based on the encouraging results from this evaluation, it is apparent that applet-based teaching approach is pedagogically driven (in coherence with Foley and Schuck, 1998; Shaw and Pieter, 2000), content specific (supported by Hughes and Hagie, 2005), dynamically designed (supported by Agarwal and Day, 1998; McCreanor, 2000) with high level of interaction (in line with Agarwal and Day, 1998; Navarro and Shoemaker, 2000) and collaboration orientated (in line with Clark, 2003; Dewhurst, Macleod, and Norris, 2000; Navarro and Shoemaker, 2000; Yu and Yu, 2001); and it can be argued that applet-based teaching may be used effectively to supplement/replace traditionally taught courses and further be refined as a suitable long-term teaching strategy.

5.4 IMPLICATIONS

The findings of this research provide a great deal of importance for myself as I learn more about the field of education. Technology is in high demand and is almost everywhere today. The study of technology in the classroom is a positive one and should continue to be studied to help further the education of students and instructors. The fear of this, however, is that one-day; teachers might be replaced by technology. I find this idea quite frightening because technology does not provide help for the emotional development of a student in the same way that a human can provide. However, studies show that technology can increase the skills of students and this in turn could produce higher quality learning in the classroom while interacting with the instructor and other students. Using Internet technology, such as Java applets could also give the instructor more free time to focus on students who might need individual attention. Overall, this study was well worth the effort and it should be continued throughout the future to see what technology sources could help students learn more academically, socially, psychologically, and cognitively.

5.5 SUGGESTIONS FOR FUTURE RESEARCH

The primary suggestion would be to encourage replication of this study with a larger, random sample. It is quite possible that sample size plays an important role in the overall results.

Culture might also be a variable that should be looked at. The student's cultural background may play a significant factor in whether or not they are affected by the particular intervention.

This study focused only on achievement, attitude and satisfaction. Further research could also evaluate how much time students studied outside of class when different instructional methods are used.

With various methods of producing grades and grade distributions among different instructors, there would be a need to set up and use standardized grading methods and measures of performance and learning in comparative studies like this one.

There is also scope to create a new suite of interactive Java applets for visual illustration of advanced statistical concepts such as two-way ANOVA, cluster analysis, discriminant analysis, factor analysis, principal component analysis, and multiple regression analysis.

Finally, using interactive Java applets presentation in other sciences and in other disciplines would add to our understanding of the benefits of using technology in education as a whole.

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APPENDIX

APPENDIX A:

OVERVIEW OF JAVA

BACKGROUND

First developed in 1995 by Sun Microsystems, Java has become the preeminent development platform and application language for the World Wide Web (WWW).

Java has quickly risen to a global standard for Web-based application development. As stated in Java language white paper produced by Sun Microsystems in 1996: "Java is a simple, object-oriented, distributed, interpreted, robust, secure, architecture neutral, portable, high-performance, multithreaded, and dynamic language."

FEATURES OF JAVA

1. Simple

Java is an object-oriented programming language that capitalizes on C++ programming concepts, with its developers choosing to streamline the legacy application language with a structure including a simple data structure called interface, and has also done away with pointers. For developers, Java is orders of magnitude easier to work with and develop in comparison to the complexities of writing applications in Fortran, COBOL, C, C++ or its many variant languages.

Sun Microsystems' engineers also defined the structure of Java to include automatic memory allocation and garbage collection, two processes that are manual in C++. Java also has created higher level constructs to make the process of creating applications much easier to accomplish.

2. Object-oriented

By definition, Java is an object-oriented (OOP) programming language that sees events, data structures, data elements and even processes and decision points as objects. This greatly simplifies the development process as well, since each object can also have its own properties and behaviours. Properties define the data set being used and behaviours are specifically focused on the processes and methods used for creating the total object identity. Taken collectively from both a properties and behaviors standpoint, Objects are further organized into classes, which are templates for the definition of an objects' role in the programme. In the context of the Java programming language, instantiation is the creation of a new Object.

It's useful to look at OPP as a programming language that includes a tree-driven structure that has a parent-child relationship where the attributes of the parent, Objects, are inherited by the child. As there are an extensive and growing series of pre-defined classes by Object, these Objects are in turned grouped into packages that comprise the process flows in Java.

The design goals of Java rely heavily on the core functionalities of object-oriented programming including the delivery of greater flexibility, modularity and re-usability of Objects. Today OOP has replaced many other more traditional forms of programming including C++ and COBOL for example, as OOP-based programming principles provide more agility for the programming in creating more adaptable and responsive programmes.

3. Distributed

The definition of distributed computing is the use of several computers in conjunction with one another to accomplish a common task. These computers are joined through a network to increase productivity and agility of sharing data. As Java was invented when computer networks were pervasive throughout organizations, the basic concepts of the language and its commands support reading, writing, sharing and integrating data across networks assuming there is complete transparency.

4. Interpreted

As Java delivers code that is partially compiled, browsers need to have support for the Java Virtual Machine (JVM) code, which in the context of Java programming, is called bytecode. One of the greatest strengths of Java is the ability to be platform independent, and this is specifically the role of bytecode structures, which acts as the compiler for the source code from a Java application. The JVM component of any browser is completely independent of the hardware platform and operating system as it relies on the browser alone. This is significantly different to C++-based applications that require compiling for each hardware platform for which they are specifically built. A separate C++ programme needs to be compiled for Microsoft Windows, Linux, or UNIX for example.

5. Robust

A major design goal for Java as a programming language was to ensure it could quickly recover from errors, and that the reliability of this language would be very high as it would be used across many different platforms. The logic that Java relies on as a programming language focuses on quick checking for both hard and soft errors, and the ability to correct itself with a runtime error checker. The design goal of having Java being able to correct errors quickly and continue functioning has been achieved, fulfilling the goal of making this programming language robust.

6. Secure

Another major design goal is to achieve security at both the server and browser level. All components of the Java language including its compiler, interpreter, or JVM, and runtime environment were initially designed with security as a key design goal and have since been augmented with more features since the launch of this programming language.

Each of the Java components including the compiler, interpreter, and JVM-based portion of the browser each support several levels of security. These components are also designed to conform to a variety of compliance and security standards, including high levels of data encryption. Java's design goal of being platform independent has also forced a higher level of security into the entire operating environment for this programming language. As a result, Java's security is even more advanced than many military systems.

7. Architecture Neutral

Of all the design goals of the development team which completed Java, the most impressive goal is the ability to deliver an entire programming environment that is architecture neutral. This term refers to the ability of the platform to be independent of any operating system. In other words this translates into having the JVM run on Microsoft Windows, Apple Macintosh operating systems, or the many variations of Linux. This is because the compiler for Java, the JVM, resides in the browser.

8. Portable

As Java is platform independent, any application produced in this programming language is by definition portable. This means that the application can run on any platform without having to be recompiled. This is one of the major reasons why developers are continually choosing Java as a development language; its code can be used across a wide variety of platforms and in many different browsers.

9. High Performance

Java's design as programming structure forces applets to be first interpreted and compiled, which saves significant time in actual execution. This is significantly different from C, C++ or other programming languages where the code is already compiled. While C++ for certain applications may be faster, the pre-compiled aspect of Java makes the applications much more portable across platforms.

10. Multithreaded

The ability of a programme to perform multiple tasks through the use of either dedicated or shared memory is called multithreading. When an application is multi-threaded, it is specifically designed to allow for more than one task to be completed at the same time. Downloading an instructional video and listening to it at the same time is an example of multithreading, as is the reading of e-mail and listening to CDs or music clips as well. Java's use of memory allocation techniques to achieve multithreading is the highest performance of any programming language.

11. Dynamic

The entire Java programming environment is dynamic and growing as developers from Sun Microsystems, IBM, Microsoft and other companies contribute to the specifications for this programming language. As an example, new methodologies, approaches and properties can be added freely in any given class without affecting the structure and performance of clients. In addition, Java also loads classes at runtime as well, further saving programming time.

In addition to the definition of new methodologies, approaches and properties, Java is capable of creating either applets or full-standing applications. As the name implies, a Java applet is a programme segment that requires a Java-enabled Web browser such as Netscape Navigator or Internet Explorer to run. Conversely Java applications are standalone programmes that require the assistance of the Java interpreter, such as the Java Virtual Machine (JVM) to run. In the context of this research, we are primarily interested in applets.

APPENDIX B:

WEB-BASED INSTRUCTION

This appendix explores Web-based instruction. Section B.1 will give an overview of Web-based instruction. Section B.2 provides the definition of Web-based instruction. Section B.3 discusses the characteristics of Web-based instruction. Section B.4 explores the advantages and disadvantages of Web-based instruction. Section B.5 will look at the importance of Web-based instruction. In Section B.6 a comparison between Web-based instruction and Traditional instruction will be given.

By definition, Web-based instruction is a learning strategy that capitalizes on the reliability, speed and accuracy of communication the World Wide Web or intranet provides specifically for any educational or training programme delivered through a browser, such as Internet Explorer or Netscape Navigator.

B.1 OVERVIEW

The Internet has grown to over 300 million users globally (Ingram, 2000) and has a reach greater than any printed, published or electronic means of communication which civilization has ever created. The adoption curve for the Internet is faster than television globally.

Of the hundreds of millions of users of the Internet, there is everyone from students looking for information and data for reports, to homemakers looking to keep up to date on the latest cooking and medical care for their families, to literally millions of knowledge workers looking to expand their ability to interpret, analyze and present information. Based on the exponential growth of the popularity of the Internet, there has been a corresponding increase in the type and number of devices that are being created to allow anyone to access the Internet at any time. These include Personal Digital Assistants (PDAs), Web-enabled telephones and many other devices. All of these devices and approaches have led to significant growth in the areas of one-way communications including the publishing of data, yet the interactive nature of the Internet has not yet fully been realized.

B.2 DEFINITION OF WEB-BASED INSTRUCTION

There are a multitude of definitions for the concept of Web-Based instruction, several of which are provided here. Khan (1997a) defines the concept of Web-Based Instruction (WBI) as: "...a hypermedia-based instructional programme which utilizes the attributes and resources of the World Wide Web to create a meaningful learning environment where learning is fostered and supported" (p.6). Furthermore, the researchers Relan and Gillami (1997) define WBI as: "...the application of a repertoire of cognitively oriented instructional strategies within a constructivist and collaborative learning environment, utilizing the attributes and resources of the World Wide Web" (p.43).

Web-Based Instruction, also called Web-Based Training, is defined by Clark (1996) as: "Individualized instruction delivered over public or private computer networks and displayed by a Web browser. WBT is not downloaded CBT, but rather on-demand training stored in a server and accessed across a network. Web-based training can be updated very rapidly, and access to training controlled by the training provider" (p.1).

While the definitions vary significantly, they all share the same concept of enabling greater communication and relying on the Internet for delivery and interactions with students.

B.3 CHARACTERISTICS OF WEB-BASED LEARNING

Just as the number, type and level of specialization is changing significantly for each academic discipline, the same holds true with the on-line learning programmes being produced to support these academic areas.

Increasingly many students are earning their university degrees on-line, including the use of libraries and listening in and depending on the software, participating in lectures. There is also the need to make lecture content available after the class is completed as well, which is another area of Web-based learning.

At a minimum, Web-based learning programmes need to include the following:

- well-designed learning materials that include courseware that integrates text, graphics and a series of hands-on activities to learn the material.
- use of on-line media including real-time audio and video to further illustrate key concepts and application of lessons learned.
- heavy reliance on a web browser to access the materials.

- ability to quickly access content and modify it from web servers.
- reliance on the TCP/IP, HTTP and security protocols to make communication more efficient.

B.4 ADVANTAGES AND DISADVANTAGES OF WEB-BASED LEARNING

While there is quite a high level of interest in Web-based learning, it is not a solution for all distance learning programmes, and is not the panacea for all teaching strategies. There are several advantages and disadvantages of this medium and approach to teaching that needs to be kept in mind. While the Internet is ideal for distance learning, it is not suitable for those students who live in areas where Internet access is either sporadic or non-existent. The following are the advantages and disadvantages of Web-based learning (Jolliffe, Ritter and Stevens, 2001).

B.4.1 Advantages of the Web-based Learning

- Delivery of the WBI can be at any time and to virtually any place.
- Based on the lessons learned from CD ROM based learning tools, Web-based learning enhances learning through greater communication capabilities.
- By their nature of being formatted for the Web, Web-based learning programmes are easy to update.
- The one-to-many structure of Web-based learning further make it ideal for teaching a wide audience of people from a single facilitator.
- The flexibility of Web-based learning makes it possible to be either highly formal or informal in the structure of a course.
- In many of the Web-based learning programmes it is possible to have real-time communications with instructors and learn through doing, especially in the case of on-line tutorials.
- Web-based learning can make use of the materials/resources already existing on the Internet.
- Web-based learning is ideal for creating multimedia-based teaching tools that integrate text, graphics, video and animation.
- Web-based learning is capable of quickly monitoring the students' progress through a series of tests and on-line tools to gauge their understanding of concepts.

- Web-based learning provides most learners for the most part with a comfortable Web-based learning environment.
- Web-based learning allows students to progress at their own speed of development and at the specific hours they have available for completing the work.

B.4.2 Disadvantages of Web-based Learning

The majority of disadvantages for Web-based learning are more attributable to technological shortcomings and less from the actual content being delivered. As Web-based learning excels with highly structured content and lessons, it is not suitable for "soft" or highly subjective areas of teaching. Here are several disadvantages of Web-based learning programmes:

- There are several technical limitations which cause many learning environments in Web-based learning to resemble the early days of Computer-Assisted Instruction (CAI) with applications that are slow to respond to the requests from users.
- The costs of creating a Web-based learning environment, from the production of the software to the delivery and updating of it, can be high. In addition, the costs of staff to keep Web-based learning programmes up and running can be significant.
- Course development tools are increasingly requiring programming-level expertise, which makes the gaming market a more attractive area to focus on compared to on-line training applications.
- The limited bandwidth of the Internet is also making the downloading of images and streaming video much more difficult in specific regions of the world.
- Higher-end on-line learning applications require higher-end and more expensive systems to make them run efficiently.
- The greater the complexity of the applications the more thorough and more frequent the training required to have both instructors and trainers conversant with the applications' features.

B.5 IMPORTANCE OF WEB-BASED INSTRUCTION

As WBI continues to grow exponentially, the factors that are driving the use of these classes of applications needs to be considered. These include the following: the ability to complete distance education at a lower cost and more efficiently, compared with other learning alternatives including CAI, videotapes, live broadcasts, and other forms of distance teaching, (Relan and Gillani, 1997 and Santi, 1997); and providing a flexible yet content-rich platform to enable global students to attain their educational objectives outside the classroom, on their own schedules, and at their convenience (Bannan and Milheim, 1997). WBI has actually hastened the development of global distance learning by encapsulating the entire learning experience into a single electronically-delivered session. These sessions include subject matter, the provision of content, and the medium of delivery, all within a single package, which is significantly different from other mediums including Computer-Based Training (CBT) which relies on separate components for the delivery of each of these components (McManus, 1996).

Nichols (1995) predicts that: "The potential benefit from formulating evaluation methodologies for the Web [for instructional materials] depends on whether or not the Web will become a permanent medium or a passing fad? In fact, the Web will likely soon become the most popular medium for the delivery of distance education type materials" (p.3).

B.6 COMPARISON WITH TRADITIONAL INSTRUCTION: SIMILARITIES AND DIFFERENCES

In many traditional instructional settings it is very difficult to develop the more advanced skills like analysis, application, synthesis and evaluation, especially for students who are not motivated to improve their learning strategies. Unfortunately the most pervasive strategy today is a passive approach to teaching and learning, requiring little if any interaction between student and subject. This passive learning forms a culture that promotes a lack of accountability for learning.

Web-based learning however forces students to be actively involved in the learning process as they have to make sense of the available information, interpret and synthesise the findings of studies. While web-based delivery of content significantly enhances learning and critical thinking, it also forces instructors to further align their content and teaching materials specifically to the needs of students.

The traditional approach to teaching also forces attendance at a specific date and time, making it critical for the student to be in the classroom to receive the necessary information for completing the tasks and assignments. Conversely Web-based instruction is ideal for distance learning, specifically bringing content, both audio, visual and textual to students when they have the time to complete the tasks involved in the class (Saltzberg and Polyson, 1995).

Web-based instruction strategies require a higher than average level of self-discipline and promotes the development of strong time management skills. The more motivated students are attracted to these on-line programmes to attain their educational goals. On-line students in general are more goal-oriented and focused on results over and above merely attending a course. In addition to these attributes, students of on-line courses have quickly found approaches to making on-line content and learning an advantage. As a general rule, they have a much more thorough understanding of Internet technologies and the use of web browsers, educational software and applications for giving them the opportunity to attain their educational goals. WBI may also help in supplementing limited library resources, as the World Wide Web is a current, up-to-date, extensive and easily accessed information source. It may also work well for students who are not comfortable in face-to-face situations and never participate or ask questions in the classrooms, but they may now ask questions through e-mails without having to see one another (Wang et al., 2001).

The downside of Web-based learning and WBI in general is the lack of technical support when software or Internet problems occur, or worse, when a specific Web server goes off-line and there is no word on what is happening with the course content. There is also a wide variation in the performance of on-line instructors, and this is amplified in Web-based instruction methods.

Traditional compared with Web-based instruction has definite advantages and disadvantages, yet the implications of Web-based applications, tools and techniques being the future of effective learning strategies on a global scale are clear.

APPENDIX C:

GALLERY OF JAVA APPLETS (REMAINING 10 APPLETS)

(i) Histogram Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/Histogram/Histogram.html

Overview

A histogram is the most important chart for exploring the shape of the distribution of the data. Histograms are most effective with large data sets, say $n \geq 75$ to 100 or larger. When the sample size is large, the histogram can provide a reliable indicator of the general shape of the population of measurements from which the sample was drawn.

The groups of data are called classes, also known as bins, because they can be viewed as containers that accumulate data and "fill up" at a rate equal to the class frequency. In addition, the size of the class interval is also known as the bin width. Deciding on the best bin width (or equivalently the number of bins) is very crucial when constructing a histogram for a given data set. The shape of the histogram is sometimes quite sensitive to the number of histogram bins. Choosing too few bins (i.e. the bins are too wide) often hides valuable information, and choosing too many bins (i.e. the bins are too narrow) leads to a messy plot from which little information can be obtained, or what may appear to be meaningful information really may be due to random variations that show up because of the small number of data points in a bin. Some judgments must be used in selecting the number of bins so that a reasonable display can be developed. The number of histogram bins depends on the number of observations and the amount of scatter or dispersion in the data. In most cases, between 5 and 20 bins is satisfactory and that the number of bins should increase with n. As a rule of thumb, the optimal number of bins is approximately equal to the square root of the number of observations.

Level of Abstraction of Underlying Concept

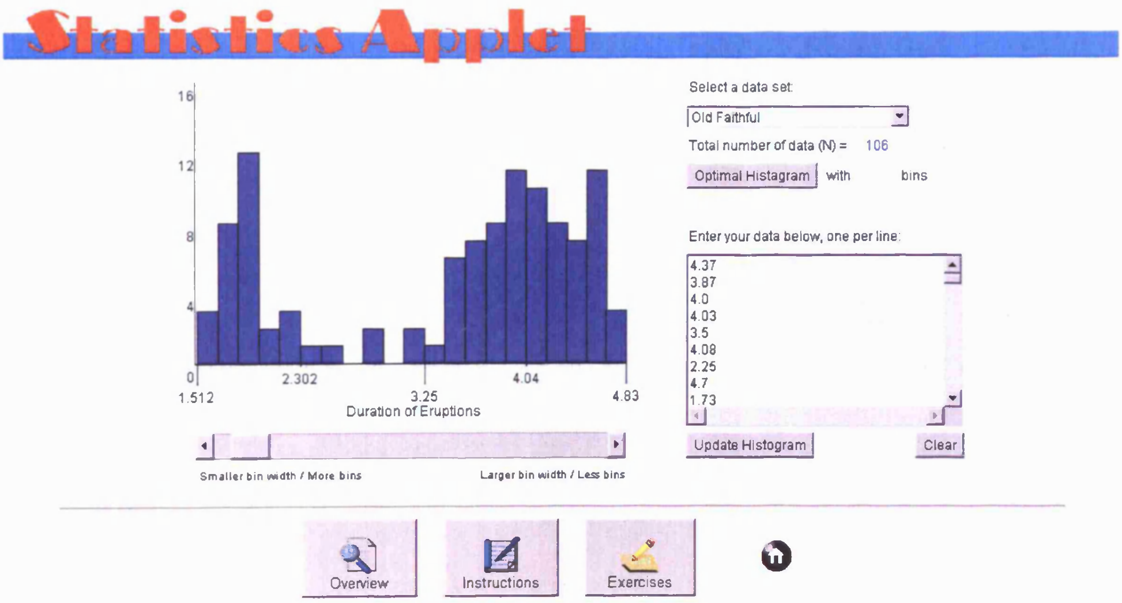
High. Students shall appreciate the importance of bin width which greatly affect the description of a data distribution. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of drawing histogram. In designing this applet, pull-down menu, slider, scroll bar and many buttons were deployed to let students to adjust the width and positions of histogram bins. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to draw a histogram with an optimal number of bins.

Objective

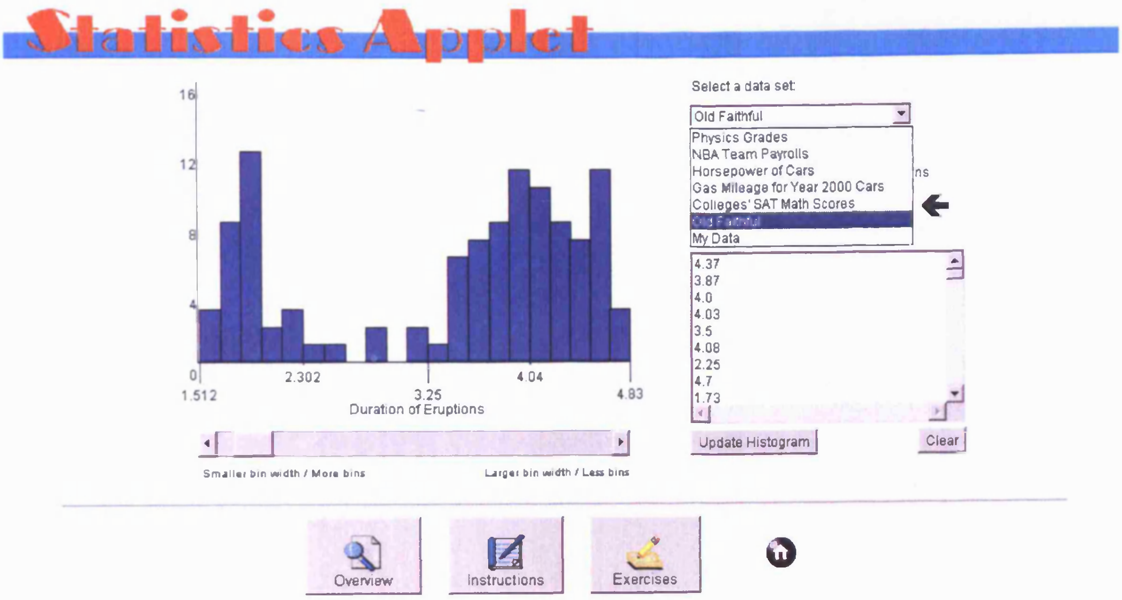
This applet is designed to demonstrate how the number of bins or bin widths can affect the appearance of a histogram. Students can also find out what bin width will provide the best picture for the given data set.

Instructions

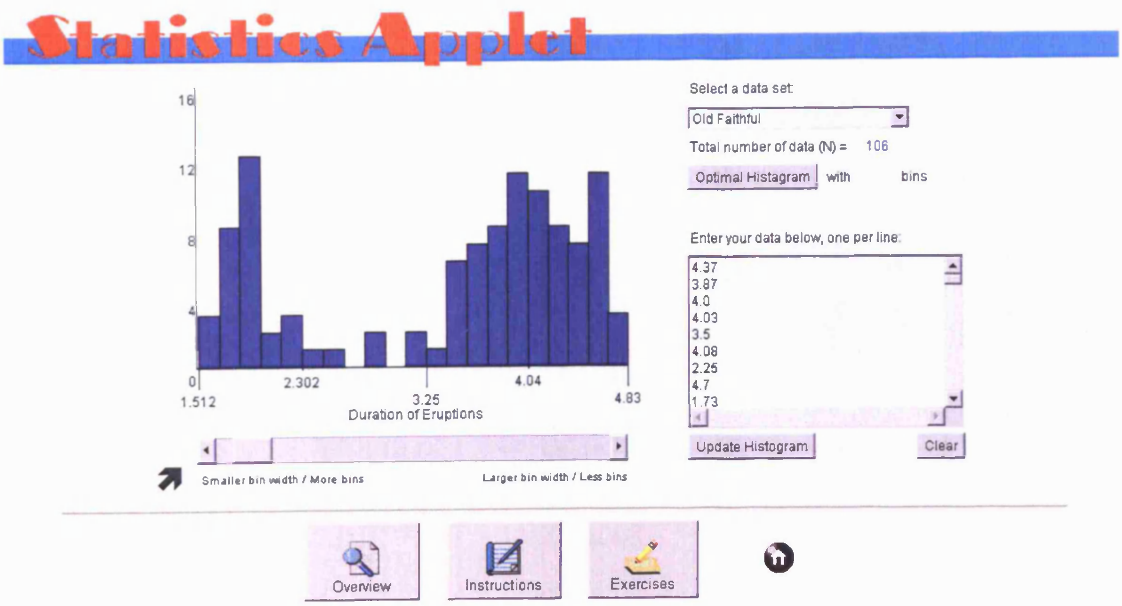
When the applet is loaded, the opening screen will appear as:



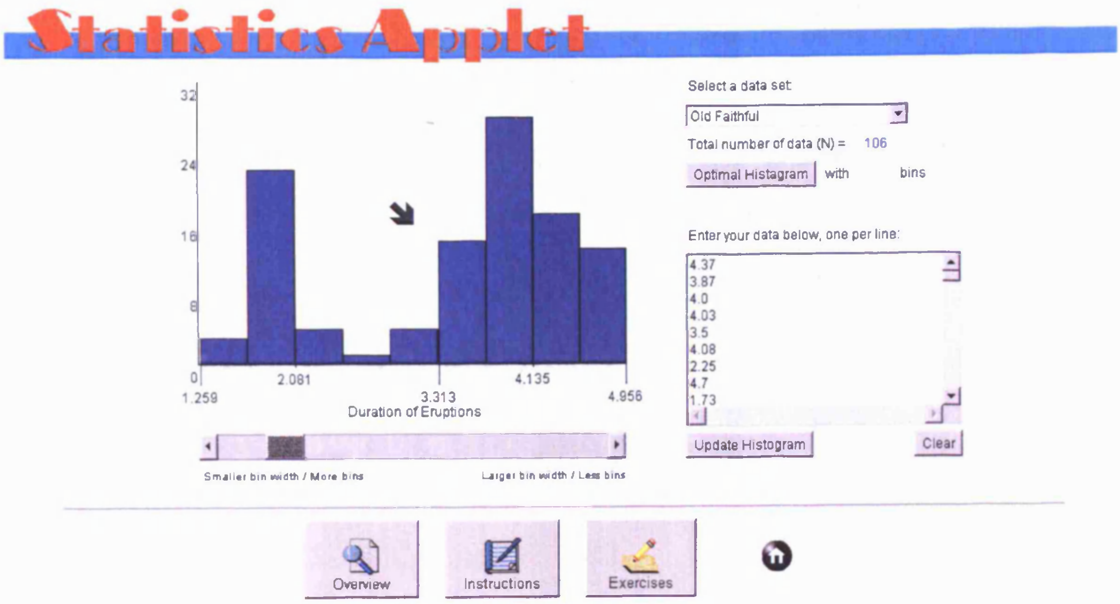
1. Choose the data to be graphed from a list of real world data sets.



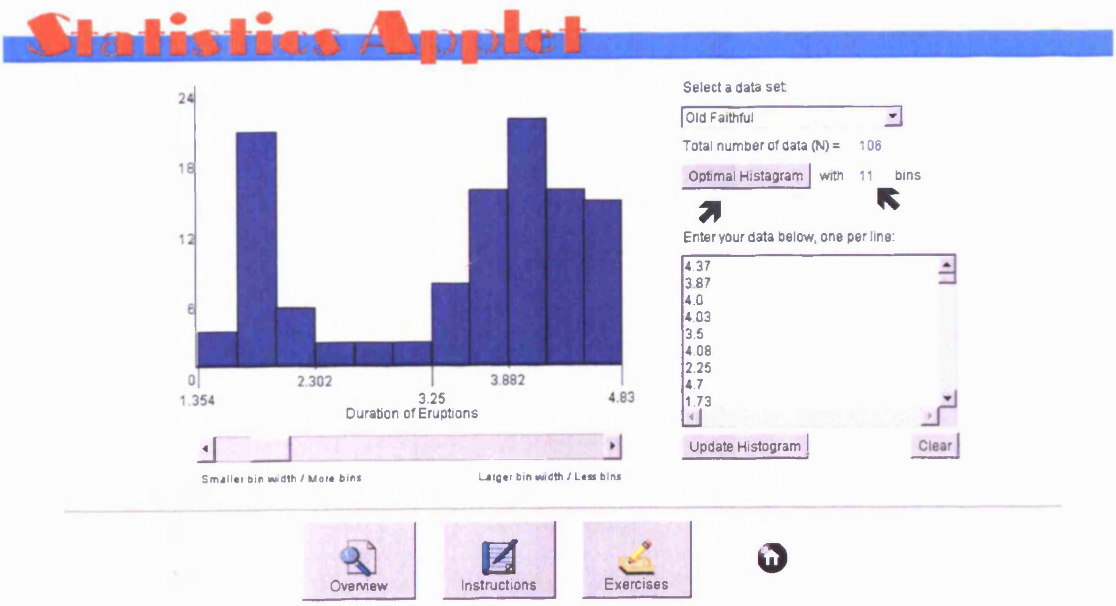
2. Move the slider bar below the histogram to alter the bin width/number of bins.



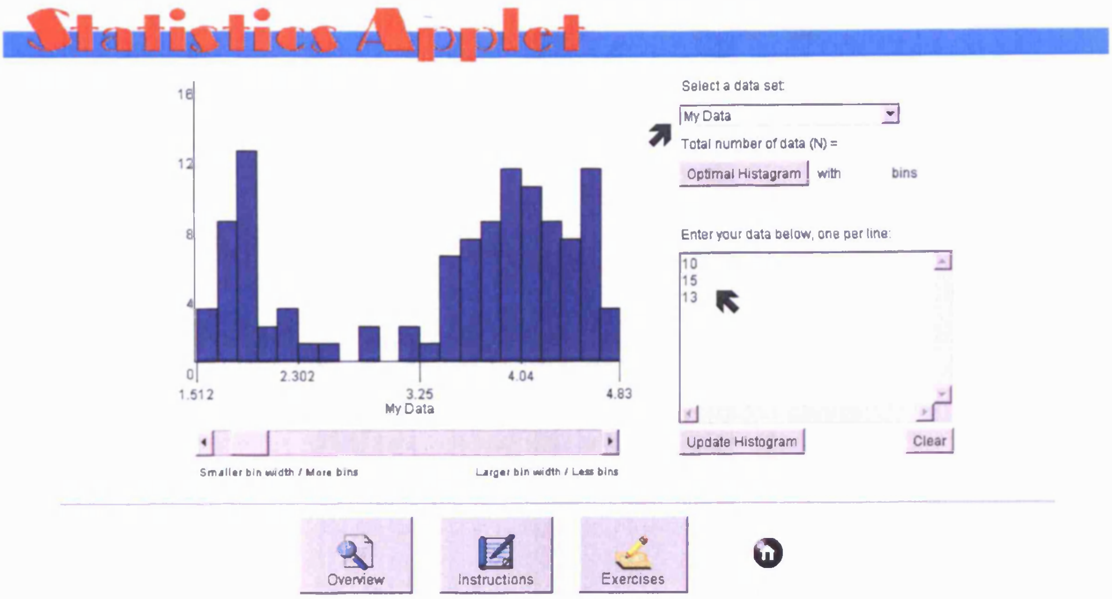
3. Histogram changes its shape accordingly.



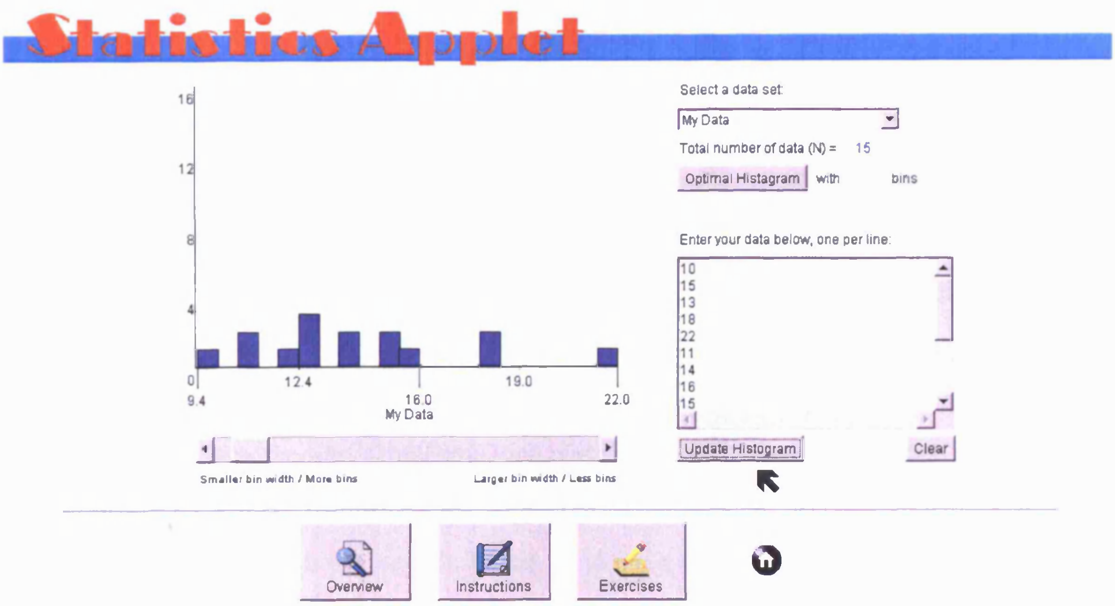
4. Click the "Optimal Histogram" button to obtain the histogram displaying the optimal number of bins.



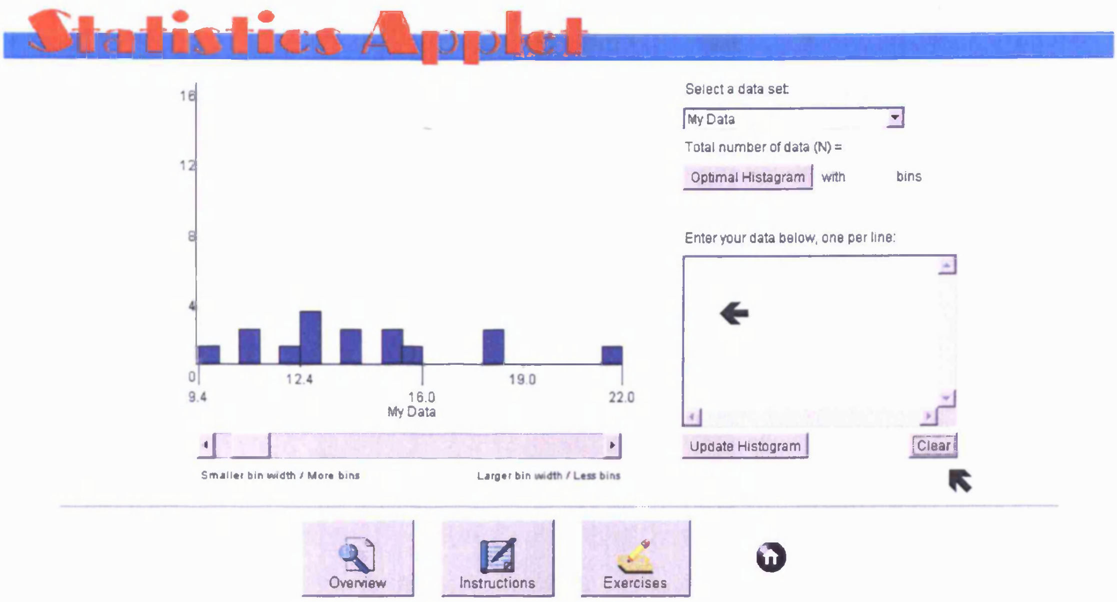
5. To enter your own data, you must input the data you want to use at the bottom of the applet. The data you want to graph should go in the data input box. Numbers in this text box should be one per line.



6. Click the "Update Histogram" button to redraw the histogram.



7. Click the “Clear” button to clear out all the data.



(ii) Addition Law of Probability Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/OrLaw/OrLaw.html

Overview

Probability is the likelihood of an event happening. If the possible events can be counted, then the probability of a specific type of event is calculated as the number of all events of that type divided by the total number of possible events. Probability is conventionally expressed on a scale from 0 to 1; a "0" probability means something can never happen whereas a "1" probability indicates something always happens.

Probabilities are based upon an experiment. An experiment is a process that leads to an outcome that cannot be determined with absolute certainty. An outcome is simply the result of an experiment. Outcomes are classified into events. An event is a subset or collection of outcomes from an experiment.

When we toss a coin, or roll a dice, or draw a ball from an urn, or draw a playing card from a well-shuffled deck of cards, it can be called an experiment. An event is one or more possible outcomes of an experiment. In the coin tossing experiment there are 2 possible outcomes - heads and tails. Similarly, in the dice rolling experiment there are 6 possible outcomes - the six faces with either one, two, three, four, five, or six dots. In the ball and urn experiment, the number of possible outcomes equal to the total number of balls. In the card experiment, there are 52 possible outcomes. Such a collection of all possible outcomes of an experiment is called sample space.

If A is an event and B is another event, then $P(A \text{ or } B)$ is the probability of either A occurring, or B occurring, or both occurring. 'Or' is commutative meaning that $P(A \text{ or } B) = P(B \text{ or } A)$.

The following formula is used to find $P(A \text{ or } B)$:

$$P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$$

This is the general case of the Addition ('Or') Law.

The Addition Law simplifies if events A and B are mutually exclusive. Two events are said to be mutually exclusive if they have no outcomes in common. More specifically, if events A and B are mutually exclusive, then the probability that both events A and B will occur is 0 [that is, $P(A \text{ and } B) = 0$], and the Addition Law can be simplified to:

$$P(A \text{ or } B) = P(A) + P(B)$$

Level of Abstraction of Underlying Concept

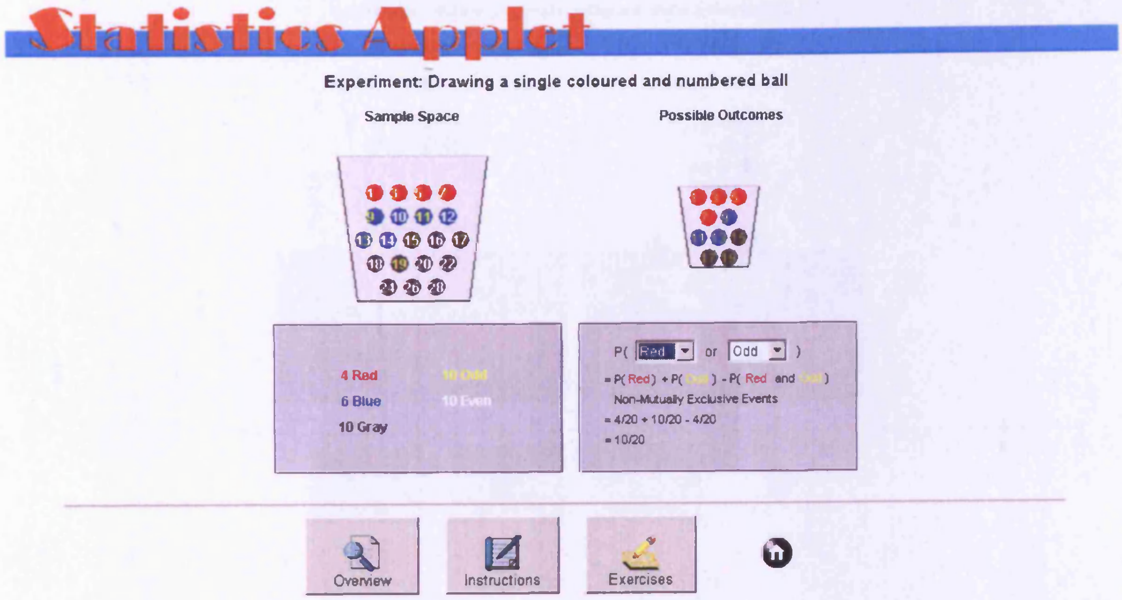
Medium. Students are often confused with the concept of mutually exclusive and non-mutually exclusive events. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the Addition Law of Probability. In designing this applet, two sets of pull-down menus were deployed to allow for interactive exploration of topic. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate probabilities involving mutually exclusive/non-mutually exclusive events.

Objective

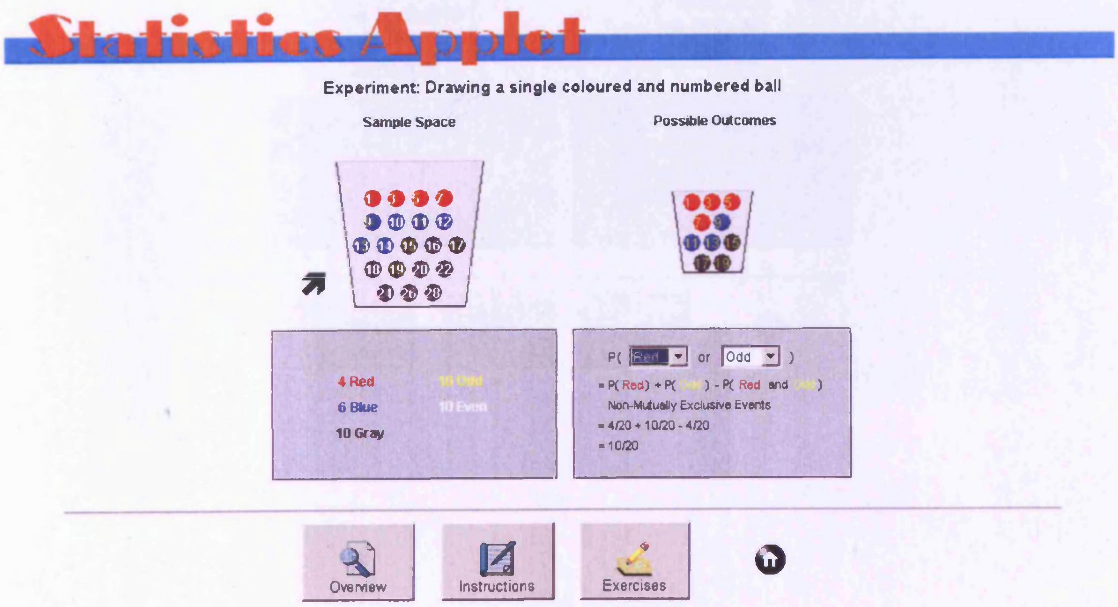
This applet is designed to demonstrate how to calculate the probability of the union of two events, i.e. the probability of the occurrence of one or the other (or both) events. Concepts of probability are important to understand because they are crucial for understanding many important controversial issues discussed in the media and in everyday conversation. They enable us to identify rare and unusual statistical outcomes, and they are necessary for testing hypotheses about the data.

Instructions

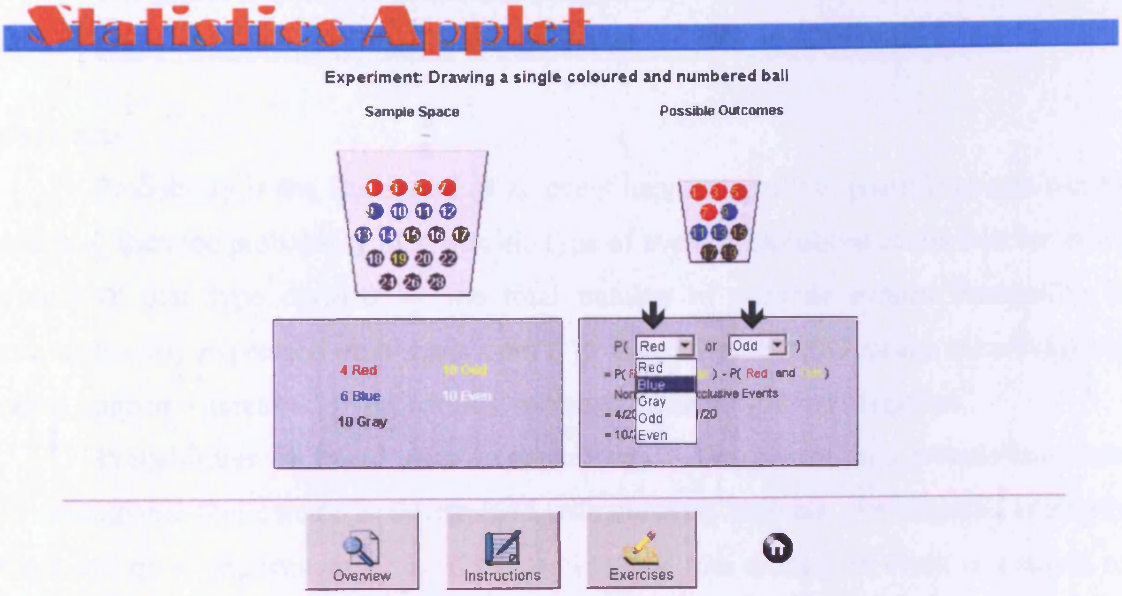
When the applet is loaded, the opening screen will appear as:



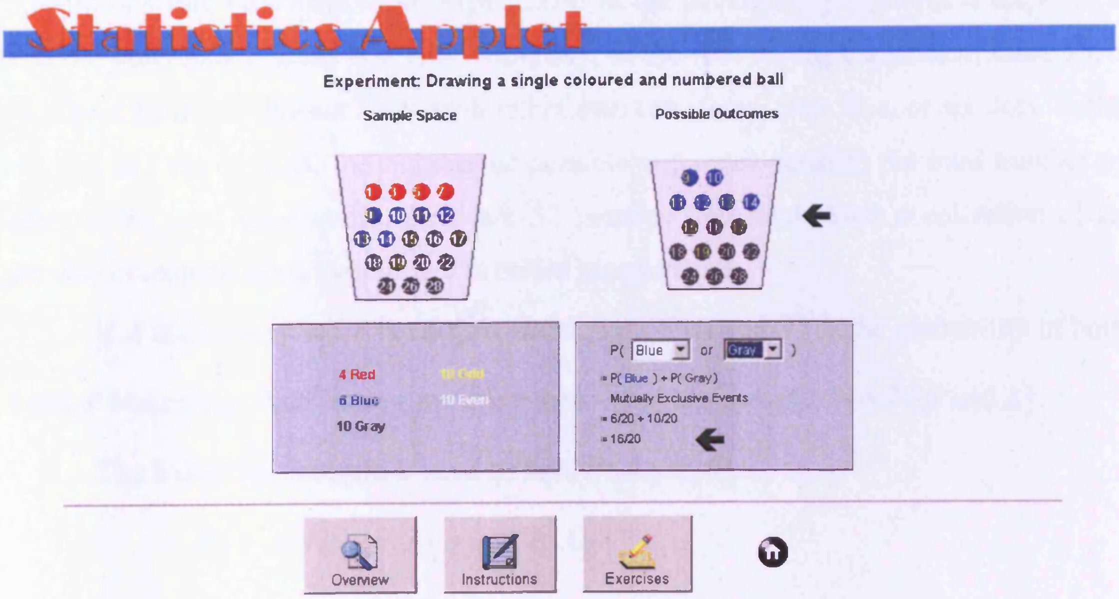
1. The top of the applet contains an urn with 20 balls. The balls are coloured red, blue, or gray and are numbered by either an even or an odd number. The ball and urn experiment consists of drawing a single ball randomly from an urn. Assume the 20 possible outcomes are equally likely.



2. Choose the ball of your preference from the list boxes.



3. The required probability will be calculated.



(iii) Multiplication Law of Probability Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/AndLaw/AndLaw.html

Overview

Probability is the likelihood of an event happening. If the possible events can be counted, then the probability of a specific type of event is calculated as the number of all events of that type divided by the total number of possible events. Probability is conventionally expressed on a scale from 0 to 1; a "0" probability means something can never happen whereas a "1" probability indicates something always happens.

Probabilities are based upon an experiment. An experiment is a process that leads to an outcome that cannot be determined with absolute certainty. An outcome is simply the result of an experiment. Outcomes are classified into events. An event is a subset or collection of outcomes from an experiment.

When we toss a coin, or roll a dice, or draw a ball from an urn, or draw a playing card from a well-shuffled deck of cards, it can be called an experiment. An event is one or more possible outcomes of an experiment. In the coin tossing experiment there are 2 possible outcomes - heads and tails. Similarly, in the dice rolling experiment there are 6 possible outcomes - the six faces with either one, two, three, four, five, or six dots. In the ball and urn experiment, the number of possible outcomes equal to the total number of balls. In the card experiment, there are 52 possible outcomes. Such a collection of all possible outcomes of an experiment is called sample space.

If A is an event and B is another event, then $P(A \text{ and } B)$ is the probability of both A and B occurring. 'And' is commutative meaning that $P(A \text{ and } B) = P(B \text{ and } A)$.

The following formula is used to find $P(A \text{ and } B)$:

$$P(A \text{ and } B) \;=\; P(A) \cdot P(B|A)$$

where $P(B|A)$ is the conditional probability that B will occur, given that A has already occurred. This is the general case of the Multiplication ('And') Law.

The Multiplication Law simplifies if events A and B are independent. Two events are said to be independent if the occurrence of one has no effect on the probability of the occurrence of the other. More specifically, if events A and B are independent, then A has no effect on B [that is, $P(B|A) = P(B)$], and the Multiplication Law can be simplified to:

$$P(A \text{ and } B) = P(A) \cdot P(B)$$

Level of Abstraction of Underlying Concept

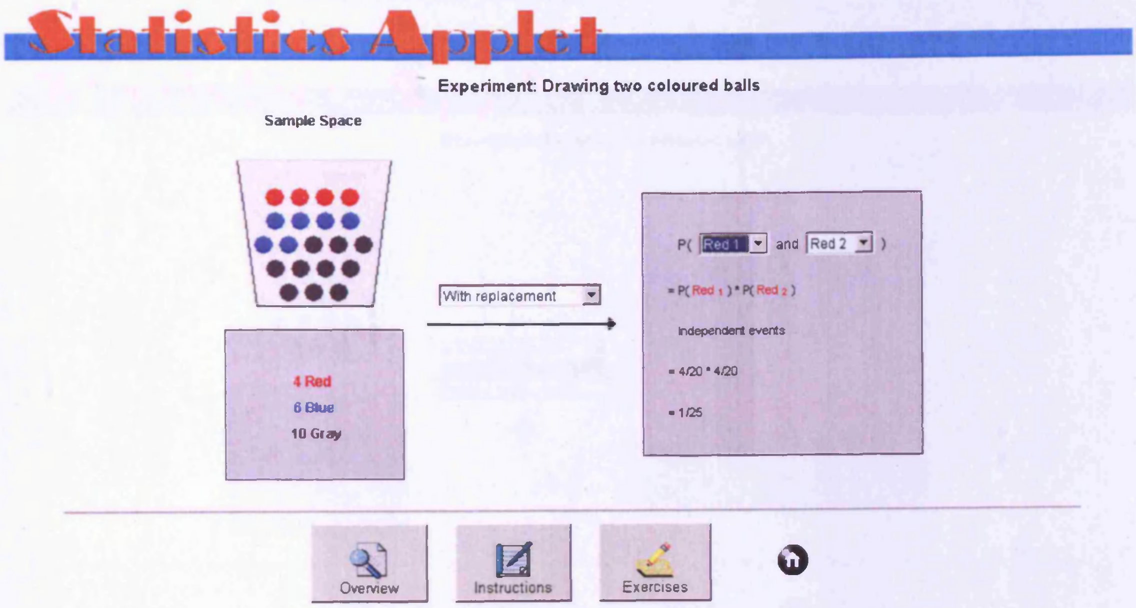
Medium. Students are often confused with the concept of independent and dependent events. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the Multiplication Law of Probability. In designing this applet, three sets of pull-down menus were deployed to allow for interactive exploration of topic. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate probabilities involving independent/dependent events.

Objective

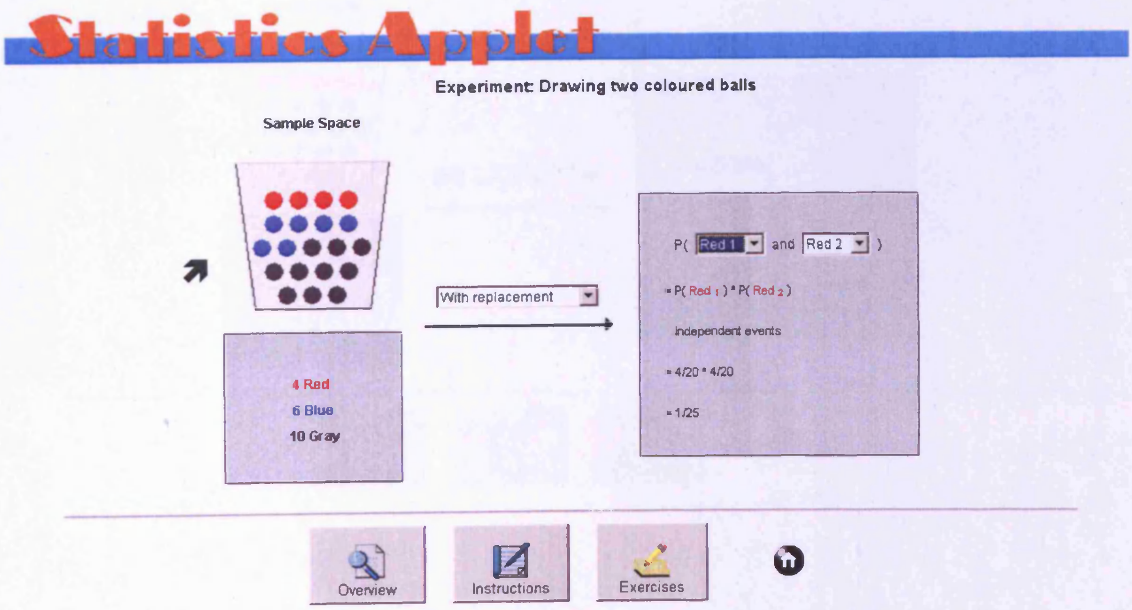
This applet is designed to demonstrate how to calculate the probability of the intersection of two events, i.e. the probability of the joint occurrence of both events. Concepts of probability are important to understand because they are crucial for understanding many important controversial issues discussed in the media and in everyday conversation, they enable us to identify rare and unusual statistical outcomes, and they are necessary for testing hypotheses about the data.

Instructions

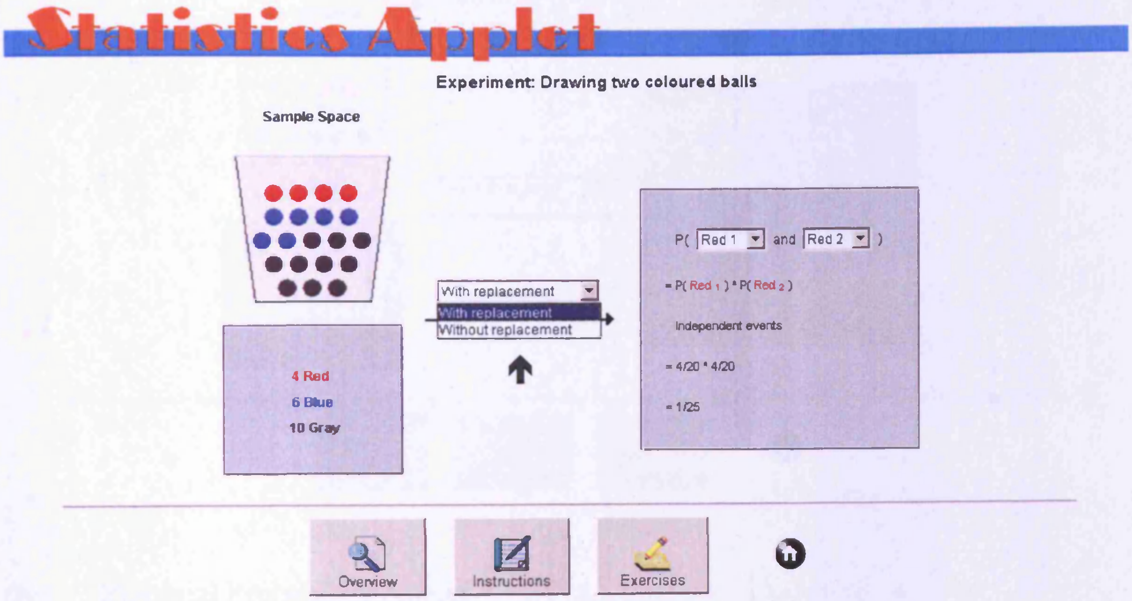
When the applet is loaded, the opening screen will appear as:



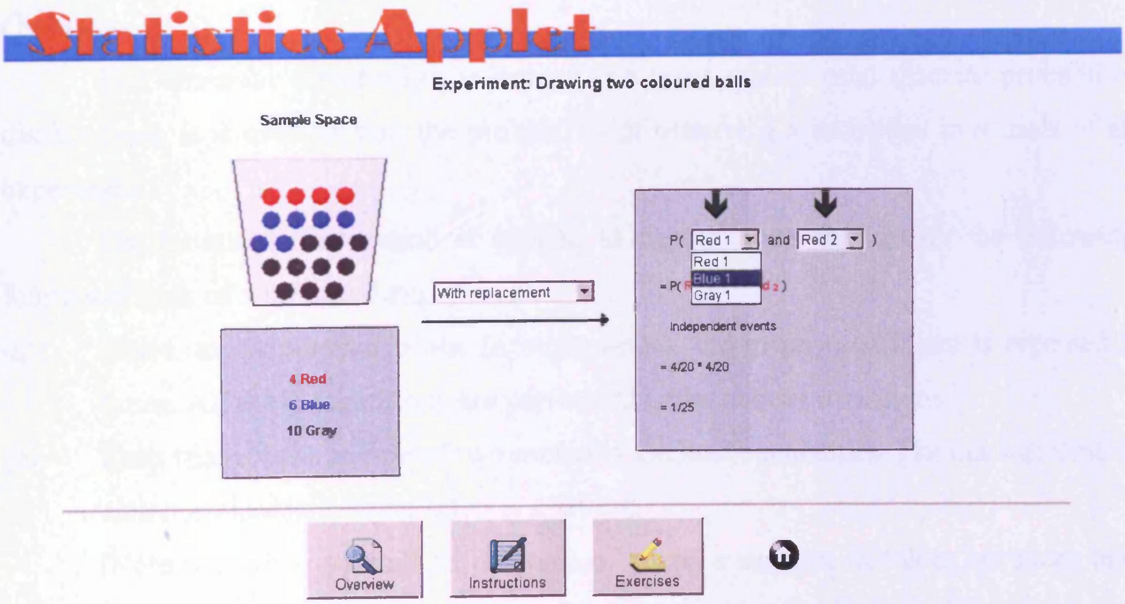
1. The top of the applet contains an urn with 20 balls. The balls are coloured red, blue, or gray. The ball and urn experiment consists of successively drawing two balls randomly from an urn, with or without replacement. Assume the 20 possible outcomes are equally likely.



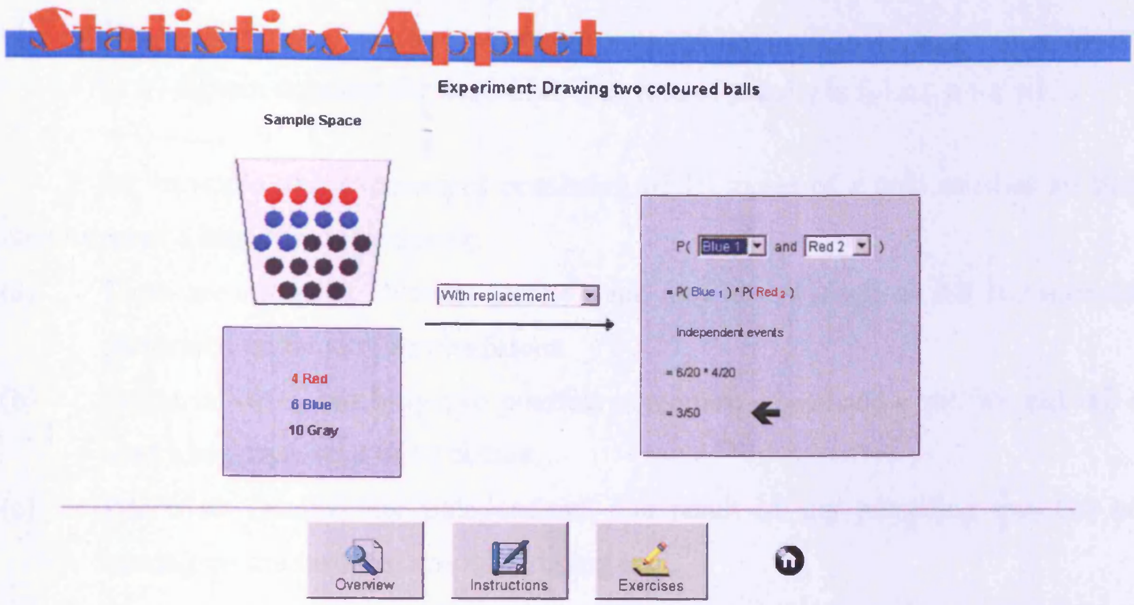
2. Choose sampling with replacement (first ball drawn is returned to the urn before the second draw) or sampling without replacement (first ball drawn is not returned to the urn) from the list box.



3. Choose the balls of your preference from the two list boxes.



4. The required probability will be calculated.



(iv) Binomial Probability Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/BinomialProb/BinProb.html

Overview

The binomial distribution is one of the most widely used discrete probability distributions. It is used to find the probability of observing x successes in n trials of an experiment.

The binomial distribution is applied to experiements that satisfy the following four conditions of a binomial experiment.

(a) There are n identical trials. In other words, the given experiment is repeated n times. All these repetitions are performed under similar conditions.

(b) Each trial results in one of two mutually exclusive outcomes. The one outcome is called a success, and the other is a failure.

[Note that when we call an outcome of a trial a success, this does not mean that the outcome is considered favourable or desirable. Similarly, a failure does not necessarily refer to an unfavourable or an undesirable outcome. Success and failure are simply the names used to denote the two possible outcomes of a trial. The outcome to which the question refers is usually called a success; the outcome to which it does not refer is called a failure.]

(c) Each trial is independent, i.e., the outcome of one trial does not affect the outcome of any other trial.

(d) The probability of success (denoted by p) and the probability of failure (denoted by q) remain constant for each trial. The sum of p and q is 1, i.e., $p+q=1$.

For example, the experiment consisting of 10 tosses of a coin satisfies all four conditions of a binomial experiment.

(a) There are a total of 10 trials (tosses), and they are all identical. All 10 tosses are performed under similar conditions.

(b) Each trial (toss) has only two possible outcomes: a head and a tail. We can call a head a success and a tail a failure.

(c) The trials (tosses) are independent. The result of any preceding toss has no bearing on the result of any succeeding toss.

(d) The probability of obtaining a head (a success) is $1/2$ and that of a tail (a failure) is $1/2$ for any toss. The sum of these two probabilities is 1. Also, these probabilities remain the same for each toss.

Therefore, the experiment consisting of 10 tosses of a coin is an example of a binomial experiment.

To find the probability of x successes in n trials for a binomial experiment, the only values needed are those of n and p, where n is the total number of trials and p is the probability of success on each trial. These are called the parameters of binomial distribution or simply the binomial parameters. To solve a binomial problem, we can find the probability of exactly x successes in n trials by using the binomial formula:

$$P(x) = \binom{n}{x} \cdot p^x \cdot (1-p)^{n-x}$$

A binomial distribution with n trials and probability of success p in each trial can be represented by its shorthand notation as: Bin (n, p)

Level of Abstraction of Underlying Concept

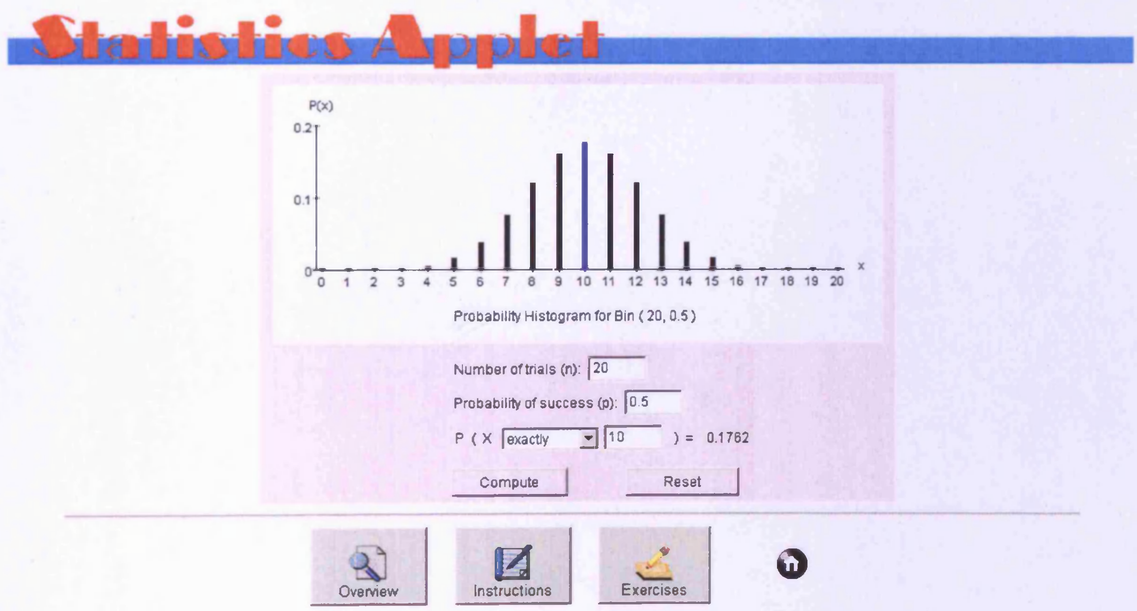
Medium. Students are often confused with calculating the probability of a discrete probability distribution. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of calculating binomial probabilities. In designing this applet, pull-down menu and value boxes were deployed to create a dynamic and interactive learning environment. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate binomial probabilities.

Objective

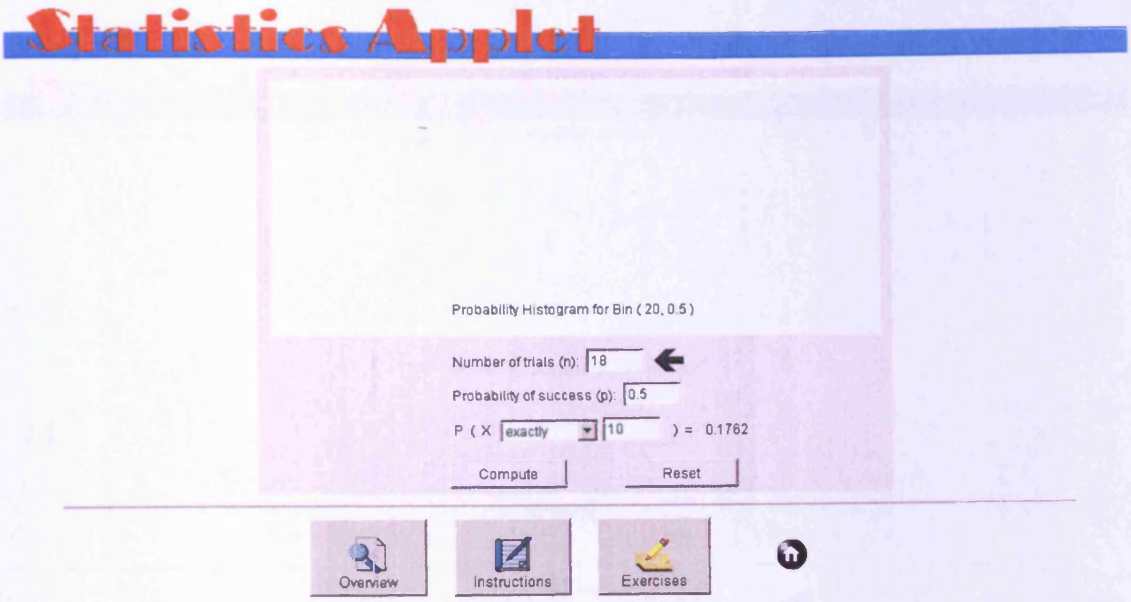
This applet is designed to calculate binomial probabilities which also show the corresponding area under the binomial probability histogram with 0 as the lower bound and *n* as the upper bound.

Instructions

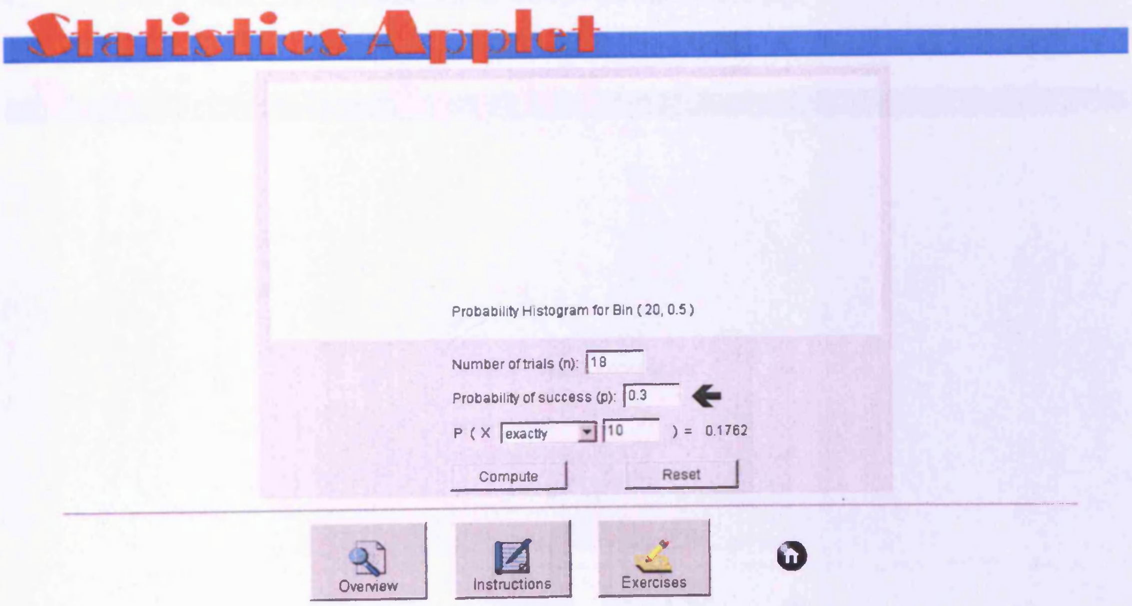
When the applet is loaded, the opening screen will appear as:



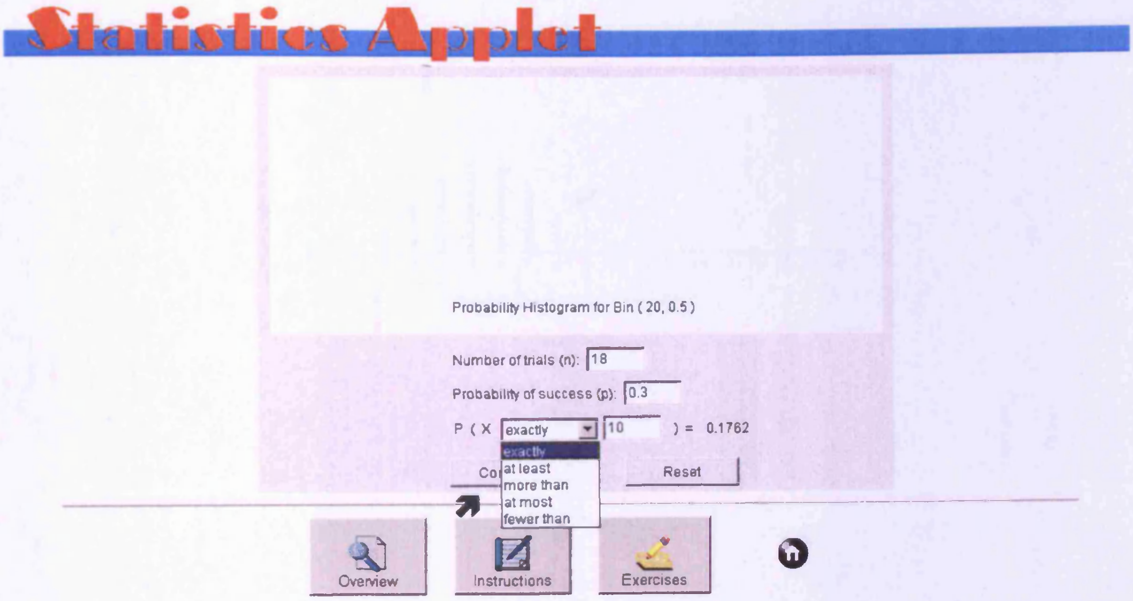
1. Input a value for the number of trials (n).



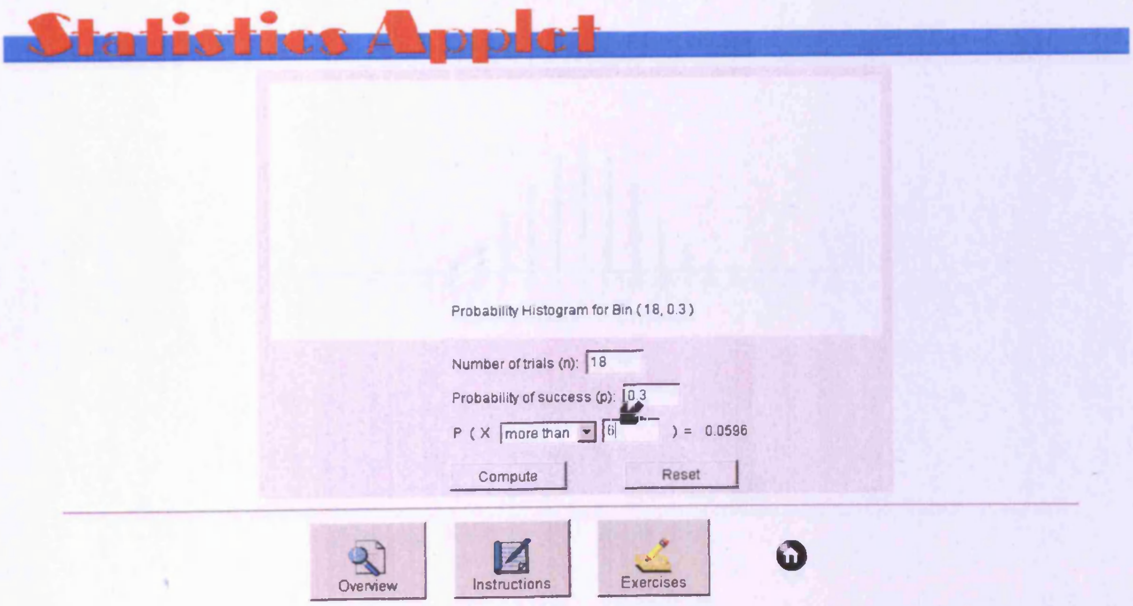
2. Input a value for the probability of success (p).



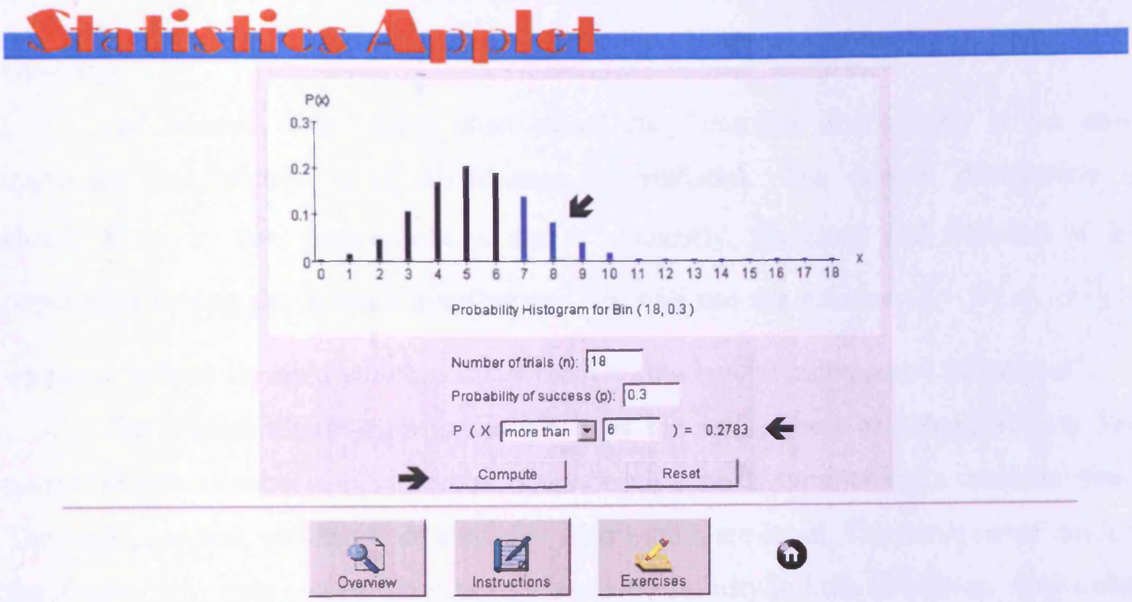
3. Depending on the type of the binomial probability question, select among choices such as "Exactly", "At least", "More than", "At most", or "Less than".



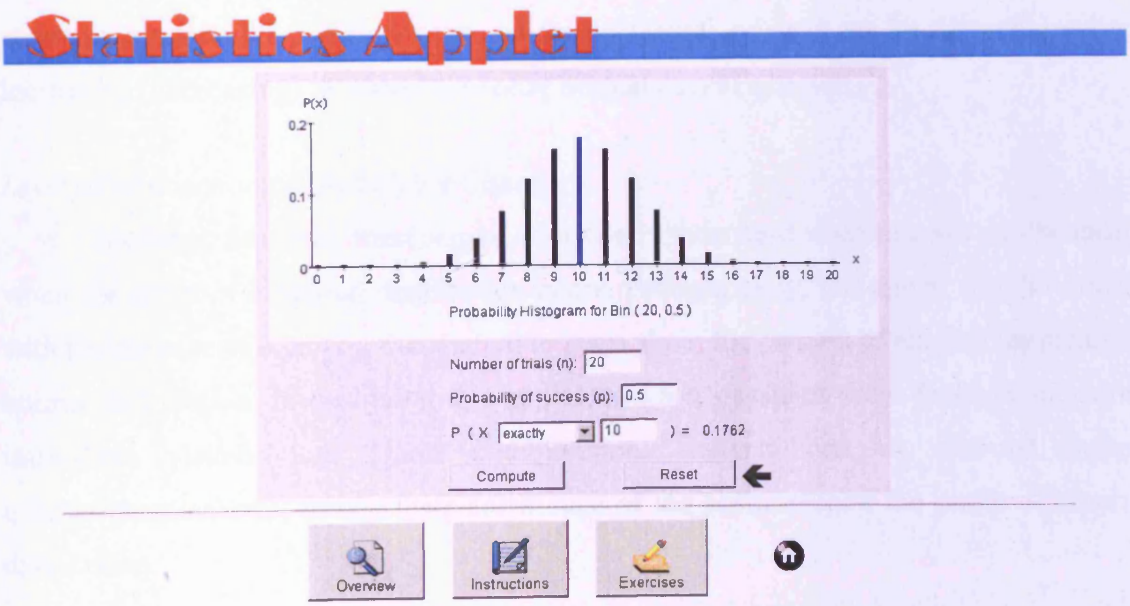
4. Input a value for the number of observed successes (x).



5. Press the "Compute" button to get the required probability. The probability is also represented as a shaded area (in blue) under the binomial probability histogram.



6. Press the "Reset" button to start over again.



(v) Normal Curve 1 Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/NormalCurve1/SliderMean.html

Overview

The normal distribution (also called the Gaussian distribution) is the most important and widely used distribution in statistics. The normal distribution is characterized by two parameters, μ and σ^2, namely, the mean and variance of the population having the normal distribution. We will use the notation $X \sim N\left(\mu , \sigma^2\right)$ to denote a random variable which is distributed normally with mean μ and variance σ^2.

The normal distribution is described by the well-known bell-shaped curve. The normal distribution curve is unimodal. The normal curve is symmetrical around the mean. The mean, median, and mode of a normal distribution are equal. The curve never touches the *X*-axis, only gets closer. The curve extends to infinity in both directions. Area under the normal curve gives probability. The total area under normal curve is 1.

The size and shape of the normal distribution is entirely determined by two parameters: the mean μ and the standard deviation σ. The value of μ determines the centre of a normal distribution curve on the horizontal axis and can be any real number. Increasing (decreasing) μ shifts the entire normal curve right (left).

Level of Abstraction of Underlying Concept

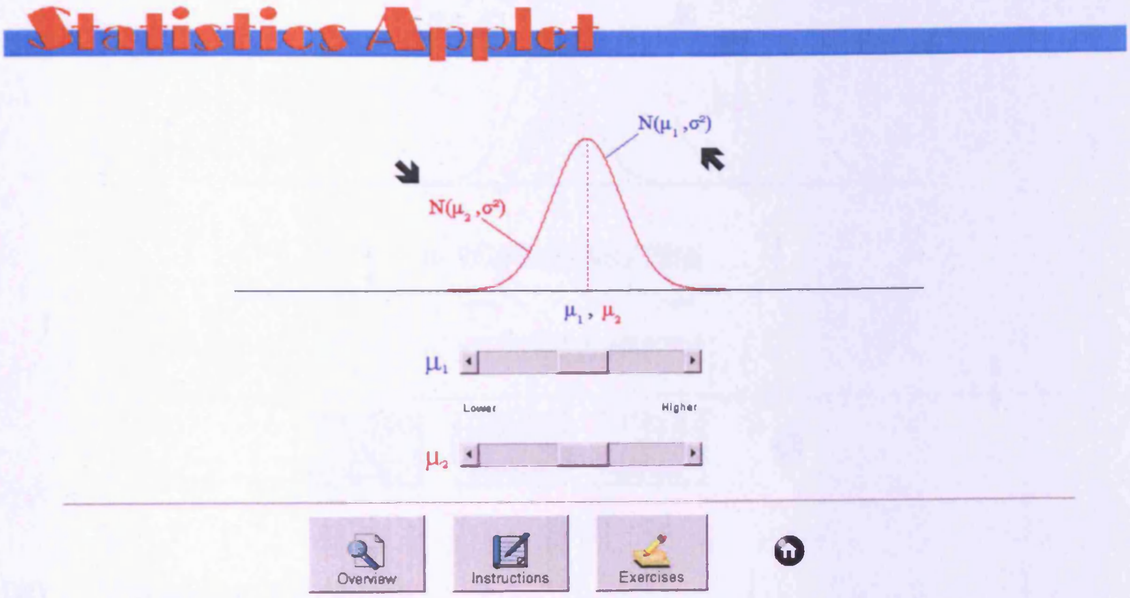
Medium. Students often cannot visualise in their head what changes will be made when the mean of a normal distribution alters. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of altering the mean of normal distribution. In designing this applet, two sets of sliders were deployed to create immediate visualisation. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of the positioning of the centre of normal distribution.

Objective

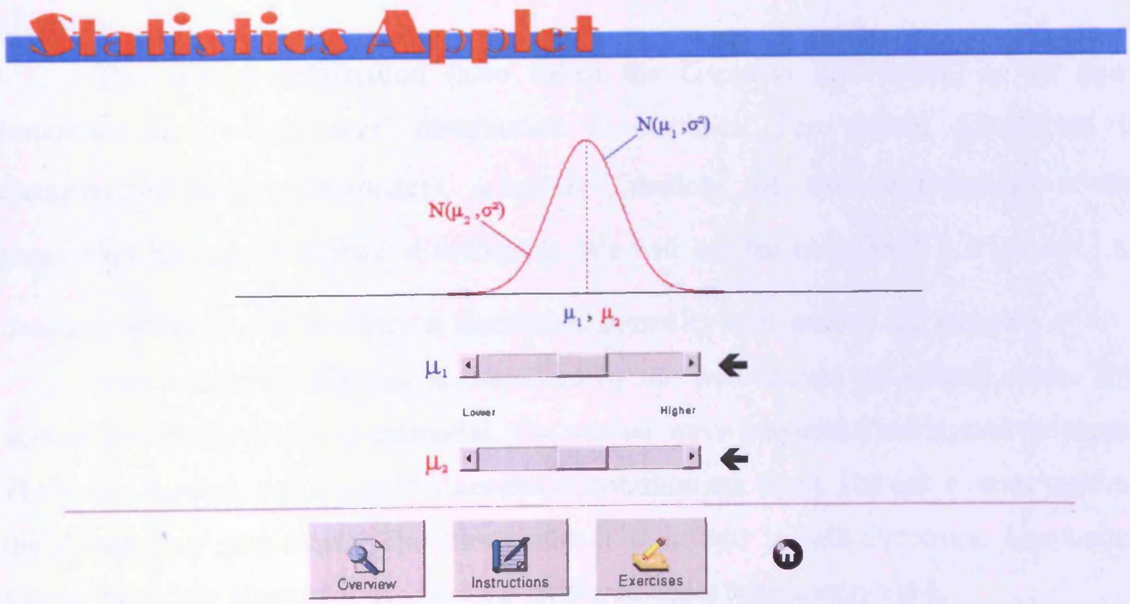
This applet is designed to demonstrate how varying the mean of a normal distribution can affect the shape of a normal curve.

Instructions

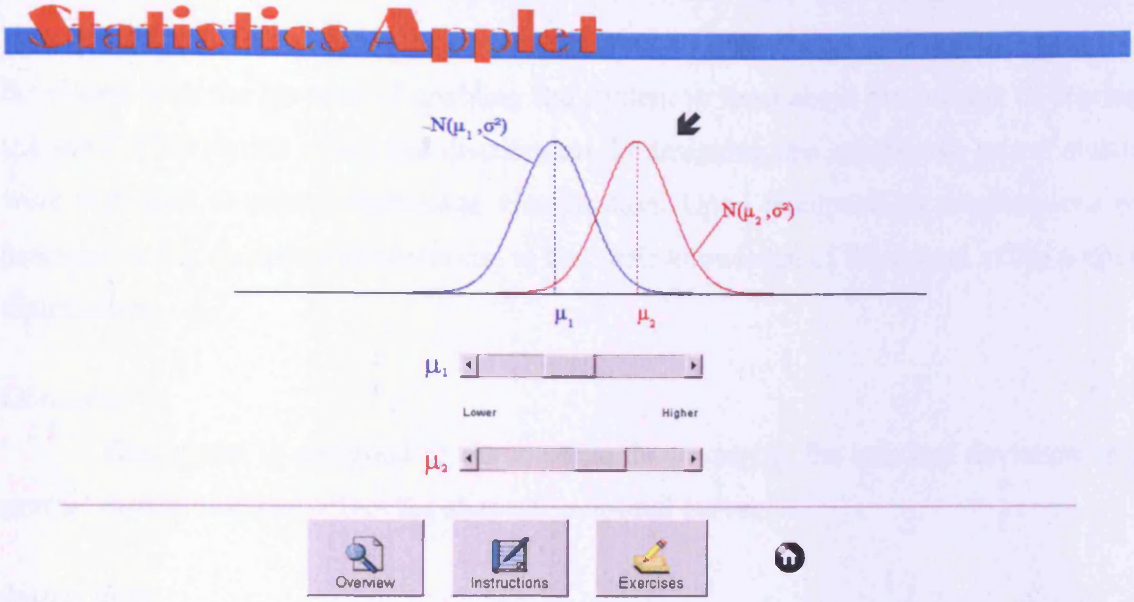
1. When the applet begins, there are two normal distributions with different means but the same standard deviation.



2. Use the slider to adjust the means of the two normal distributions.



3. The shape of the normal curve(s) will be dynamically updated.



(vi) <u>Normal Curve 2 Applet</u>

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/NormalCurve2/SliderSD.html

Overview

The normal distribution (also called the Gaussian distribution) is the most important and widely used distribution in statistics. The normal distribution is characterized by two parameters, μ and σ^2, namely, the mean and variance of the population having the normal distribution. We will use the notation $X \sim N(\mu, \sigma^2)$ to denote a random variable which is distributed normally with mean μ and variance σ^2.

The normal distribution is described by the well-known bell-shaped curve. The normal distribution curve is unimodal. The normal curve is symmetrical around the mean. The mean, median, and mode of a normal distribution are equal. The curve never touches the *X*-axis, only gets closer. The curve extends to infinity in both directions. Area under the normal curve gives probability. The total area under normal curve is 1.

The size and shape of the normal distribution is entirely determined by two parameters: the mean μ and the standard deviation σ. The value of σ gives the spread of the normal distribution curve and can be any positive real number. Increasing (decreasing) σ causes the curve to be wider (narrower).

Level of Abstraction of Underlying Concept

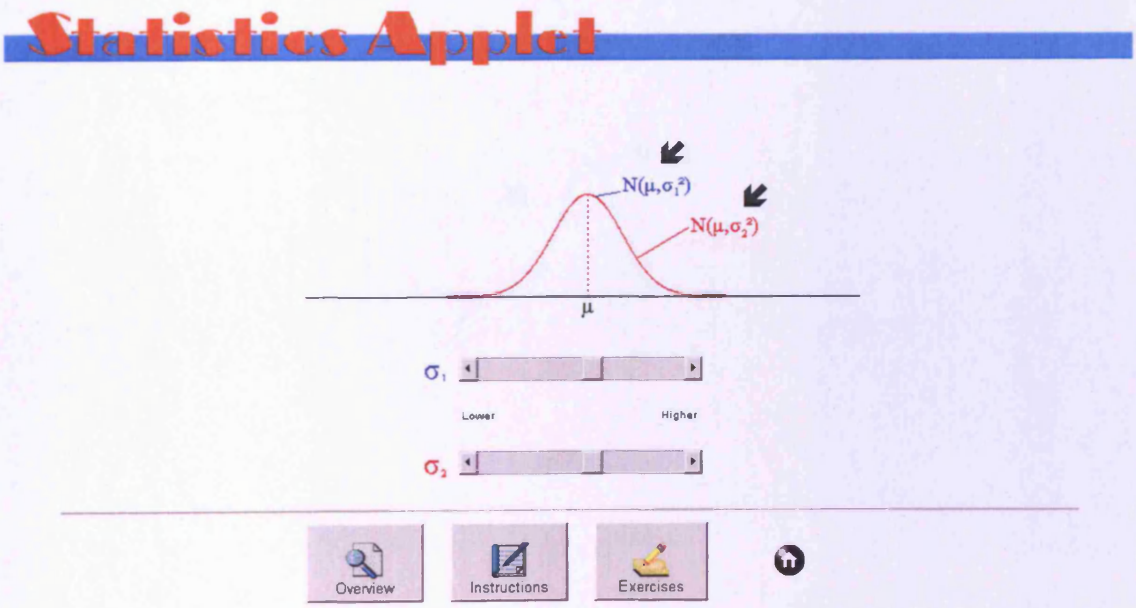
Medium. Students often cannot visualise in their head what changes will be made when the standard deviation of a normal distribution alters. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of altering the standard deviation of normal distribution. In designing this applet, two sets of sliders were deployed to create immediate visualisation. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of the spread of the normal distribution.

Objective

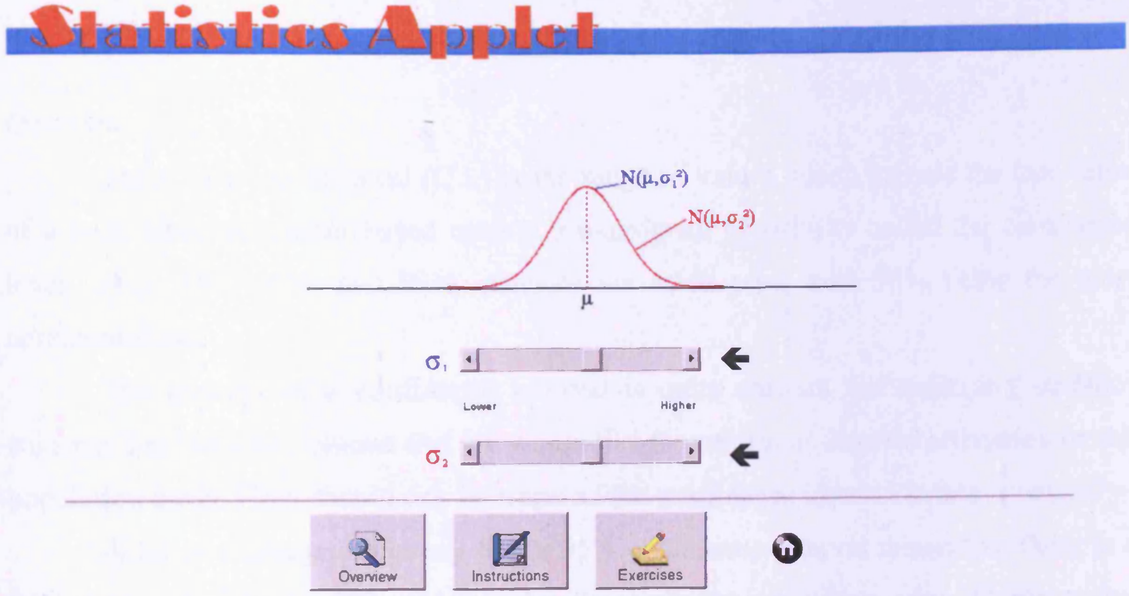
This applet is designed to demonstrate how varying the standard deviation of a normal distribution can affect the shape of a normal curve.

Instructions

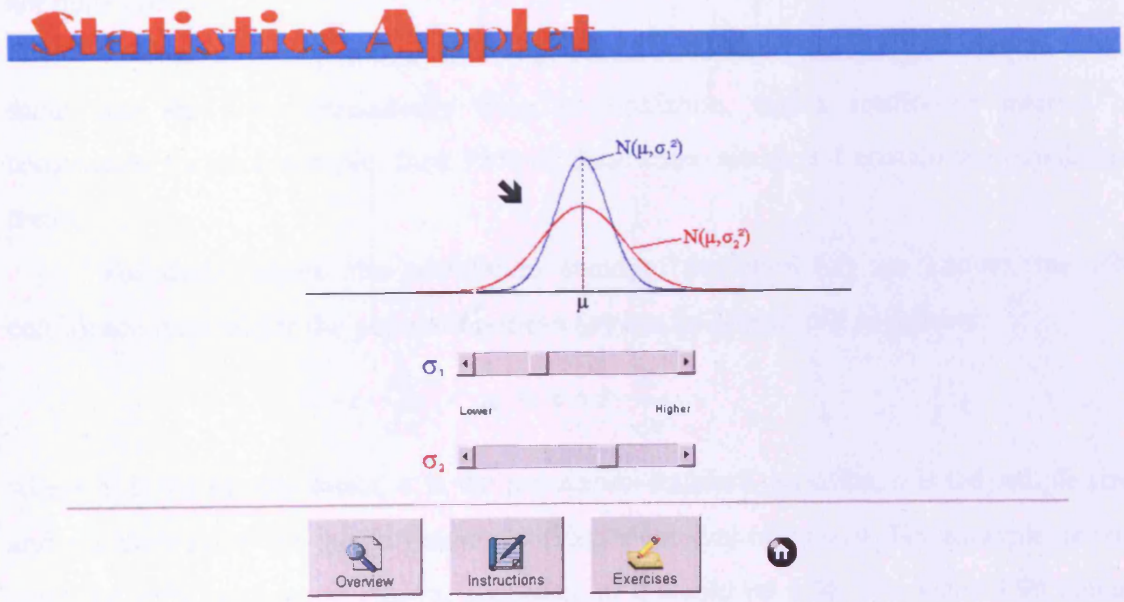
1. When the applet begins, there are two normal distributions with the same mean but different standard deviations.



2. Use the slider to adjust the standard deviations of the two normal distributions.



3. The shape of the normal curve(s) will be dynamically updated.



(vii) Confidence Interval Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/ConfidenceInterval/CI.html

Overview

The confidence interval (C.I.) is the range of values which include the true value of a population parameter based upon a pre-assigned probability called the confidence level (B%). 90%, 95%, and 99% intervals are often used, with 95% being the most commonly used.

The concept of a confidence interval is quite abstract for beginning statistics students. For instance, assume that we would like to perform an interval estimation on the population mean. How should one interpret a 95% confidence interval in this situation?

A lot of students might say that a 95% confidence interval means that there is a 95% chance that the confidence interval will contain the population mean. However any particular confidence interval either contains the population mean, or it does not contain the population mean. The confidence interval interpreted in this way as a probability is not quite correct.

The correct interpretation should be based on repeated sampling. If samples of the same size are drawn repeatedly from a population, and a confidence interval is constructed for each sample, then 95% of these intervals should contain the population mean.

For cases where the population standard deviation (σ) are known, the B% confidence interval for the population mean (μ) can be determined as follows:

$$\bar{x} - z \cdot \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + z \cdot \frac{\sigma}{\sqrt{n}}$$

where $\bar{x}$ is the sample mean, σ is the population standard deviation, n is the sample size and z is the z-score for the particular confidence interval of interest. For example, if you want the 95% confidence interval the value of z would be 1.96. The value 1.96 comes from our understanding of the normal curve.

Level of Abstraction of Underlying Concept

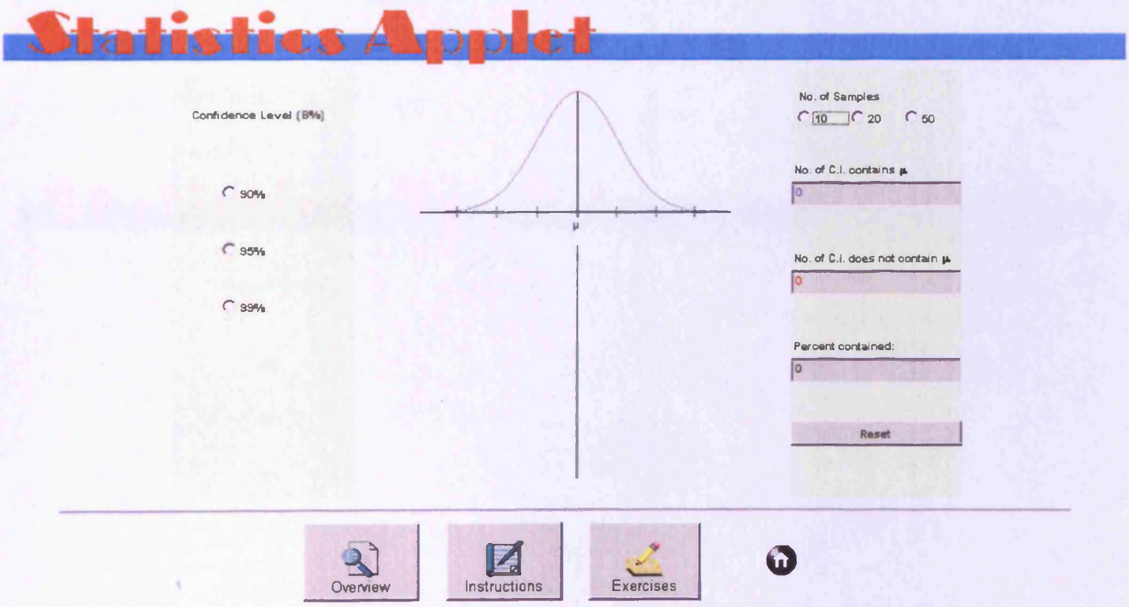
High. Students often do not understand how to interpret the meaning of a *B*% confidence interval. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of calculating confidence interval. In designing this applet, two sets of radio buttons were deployed to create a dynamic and interactive learning environment. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate confidence interval.

Objective

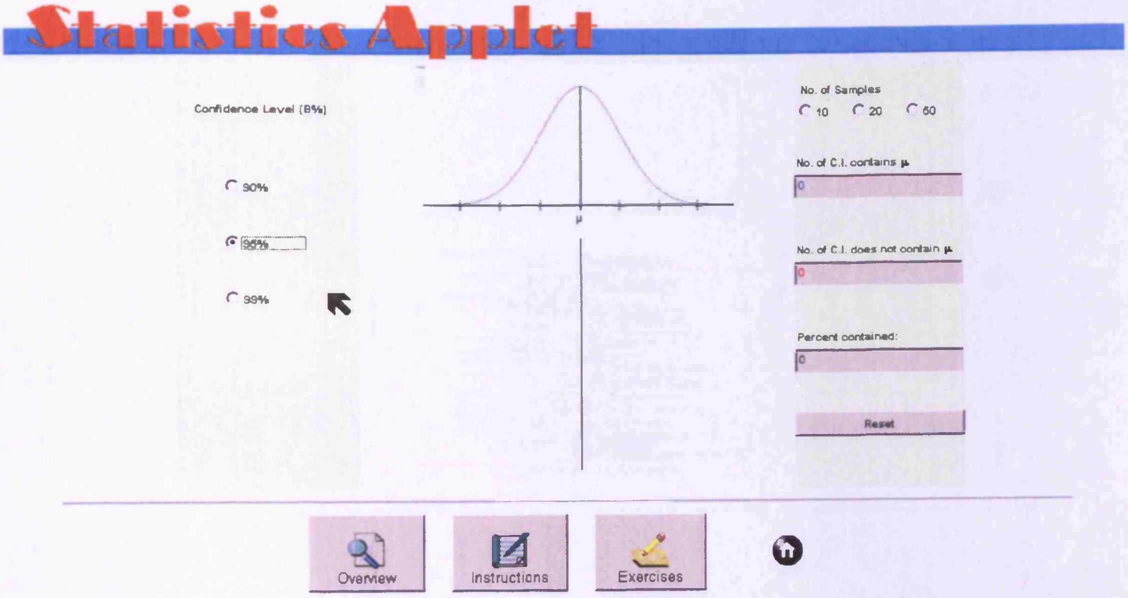
This applet is designed to demonstrate how confidence intervals are generated for simulated experiments. By changing the confidence level (*B*%) and the number of samples, students can see how these parameters affect the confidence intervals. In addition, students can gain a clearer view on what a confidence interval really means in terms of covering the true population mean μ.

Instructions

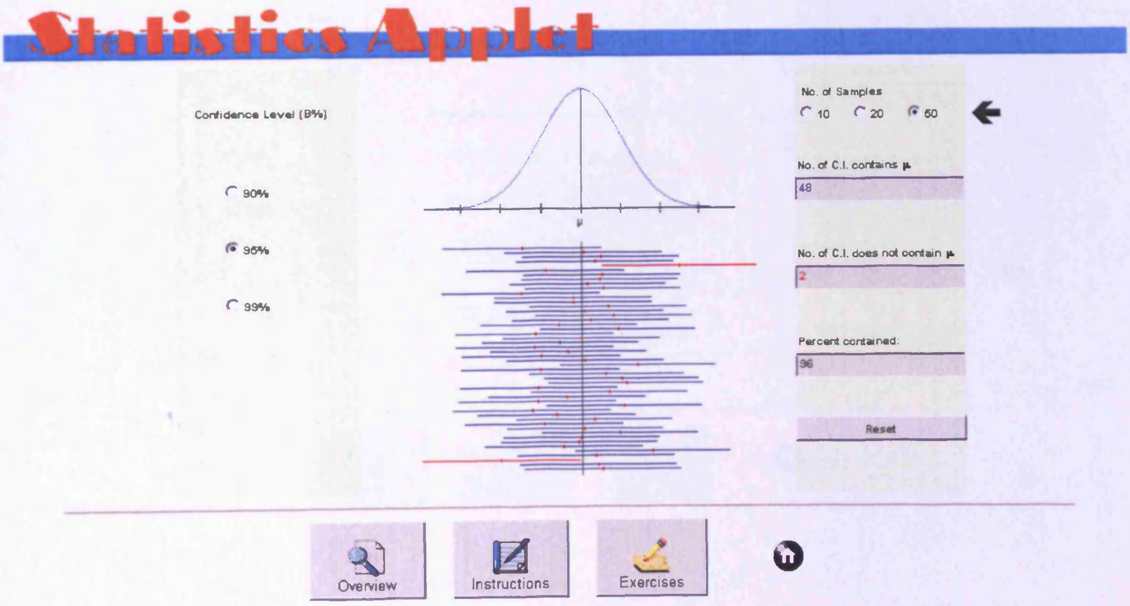
When the applet is loaded, the opening screen will appear as:



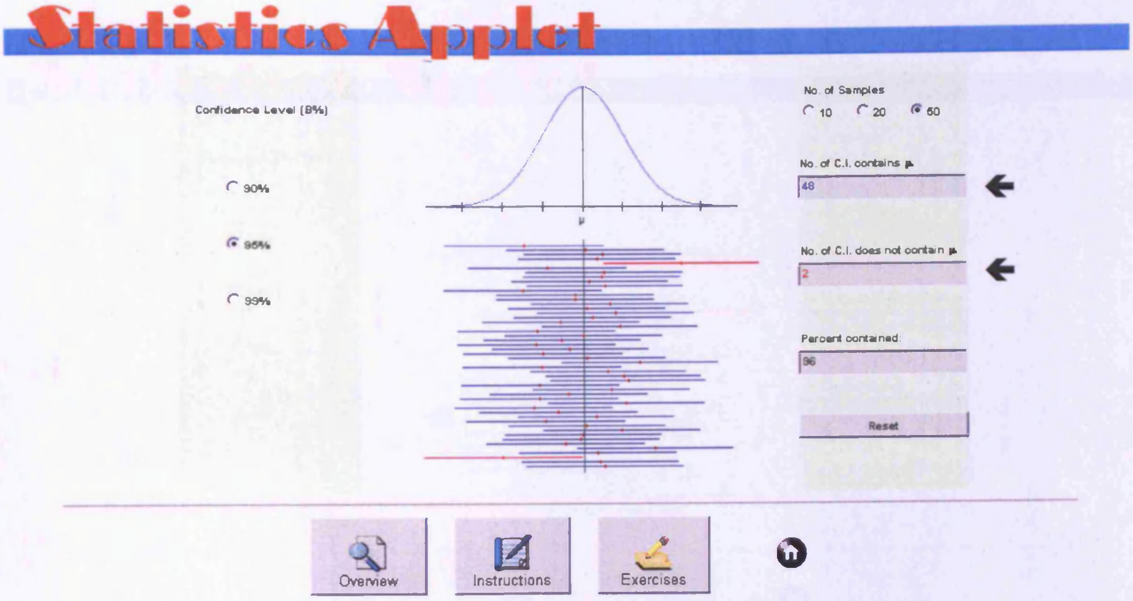
1. Set the desired confidence level (B%), from a selection of 90%, 95% or 99%, by clicking on the radio buttons to the left of the plot.



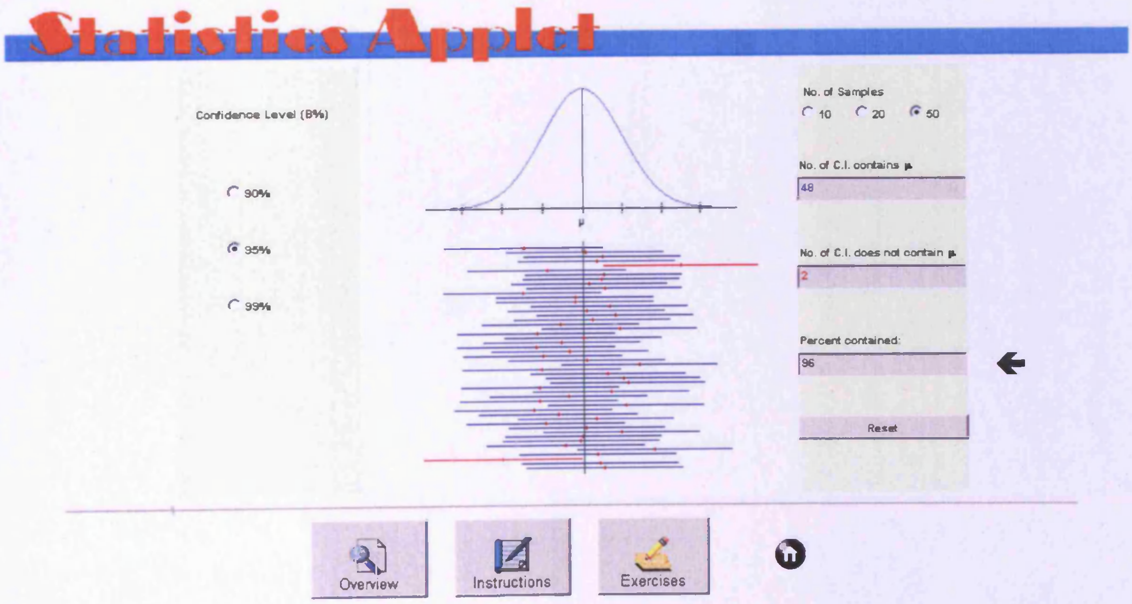
2. Set the desired number of samples, from a selection of 10, 20 or 50 random samples, by clicking on the radio buttons to the right of the plot. [Note that each time you click your desired number of samples, the results of a new set of random samples will be shown.]



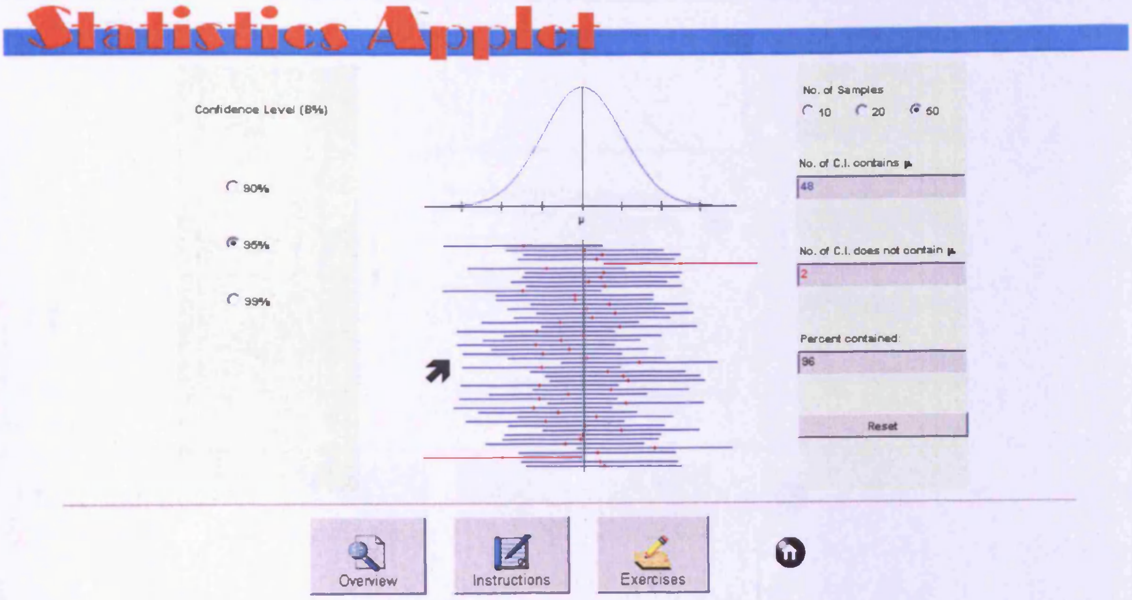
3. The number of confidence interval(s) that contains μ and the number of confidence interval(s) that does not contain μ will be dynamically updated.



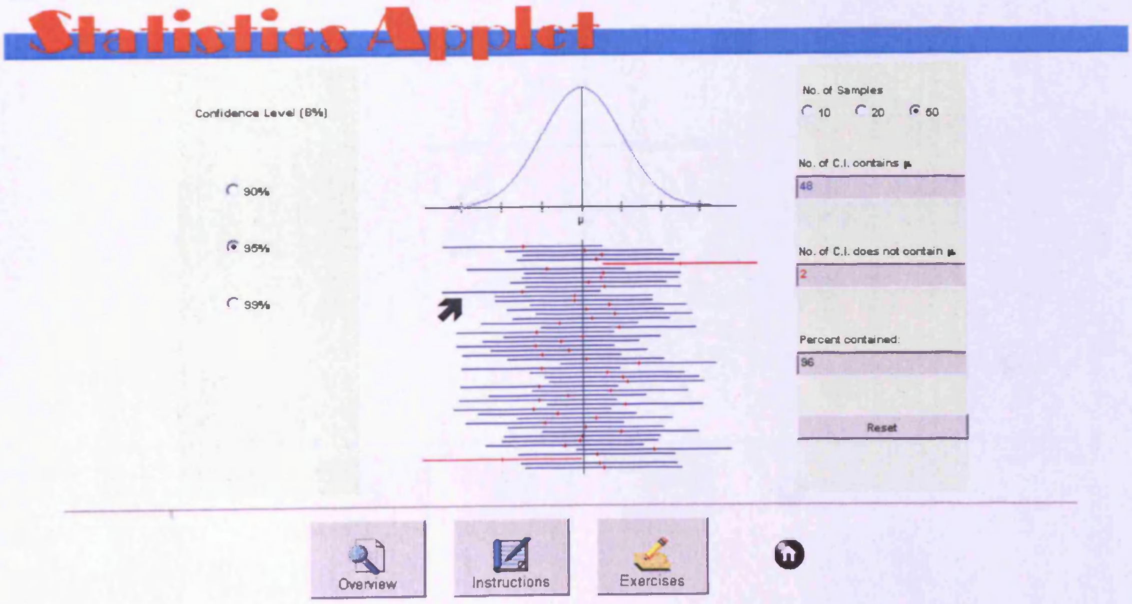
4. The percentage of the number of constructed confidence intervals covering the population mean will also be dynamically updated.



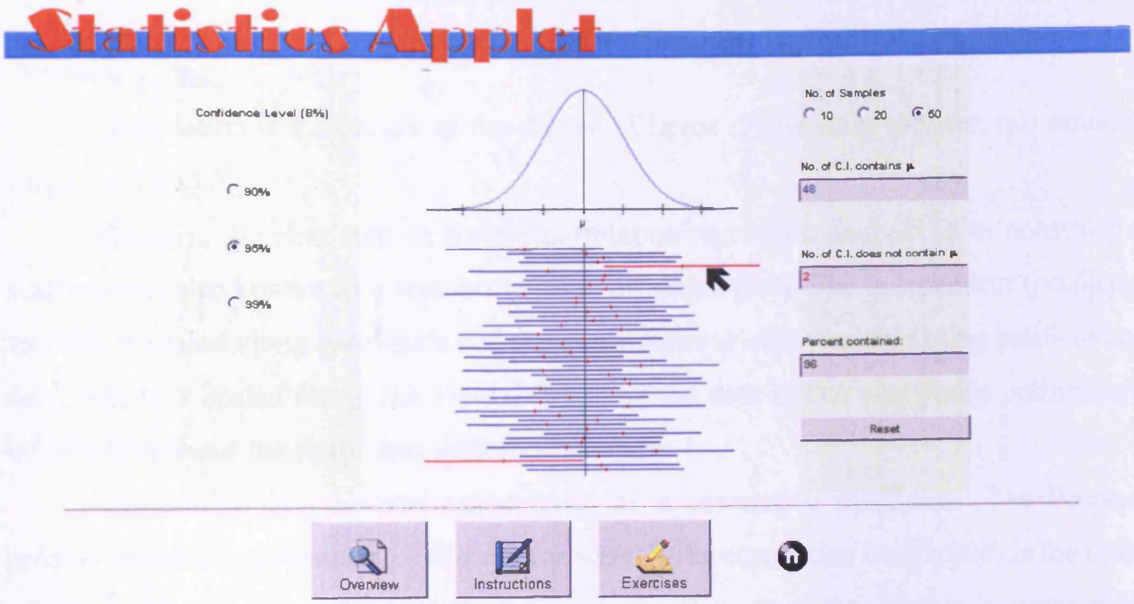
5. The intervals for the various samples are displayed by horizontal lines. The dot marks the sample mean, which is the centre of the interval. The lines on each side of the dot span the confidence interval.



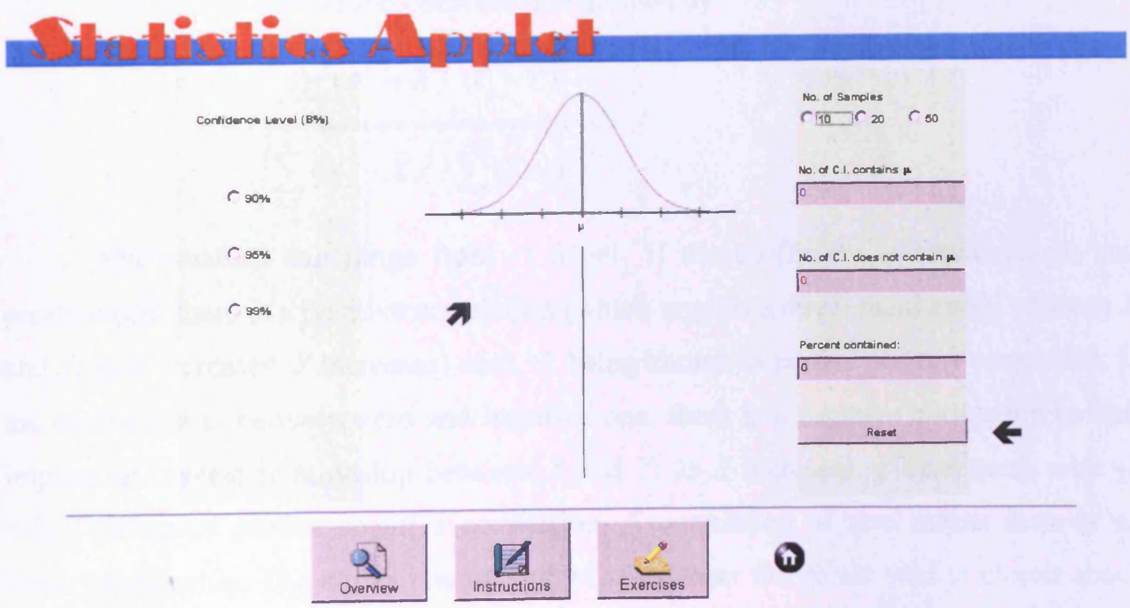
6. Blue line(s) corresponds to confidence interval(s) containing the population mean.



7. Red line(s) corresponds to confidence interval(s) not containing the population mean.



8. Press the "Reset" button to start over again.



(viii) Correlation 1 Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/Correlation1/Correlation1.html

Overview

Correlation is a measure of the degree of linear relationship between two random variables X and Y.

Usually, the first step in simple correlation/regression analysis is to construct a scattergram (also known as a scatter diagram, or scatter plot). The independent (predictor) variable is scaled along the X-axis and the dependent variable (variable being predicted or determined) is scaled along the Y-axis. Graphing the data in this way yields preliminary information about the shape and spread of the data.

Correlation is measured numerically by a correlation coefficient. The Pearson product-moment correlation coefficient (or simply, the correlation coefficient) is the most widely used measure of correlation. For population data, the Pearson's correlation coefficient is designated by the Greek letter rho (ρ). For sample data, it is designated by the lower case letter "r".

The sample correlation coefficient is defined by

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})\cdot(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \cdot \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

The r-values can range from -1 to +1. If the coefficient is between zero and positive one, there is a positive correlation (which implies a direct relationship between X and Y: as X increases, Y increases) with +1 being known as perfect positive correlation. If the coefficient is between zero and negative one, there is a negative correlation (which implies an inverse relationship between X and Y: as X increases, Y decreases), with -1 being known as perfect negative correlation. A correlation of zero means there is no linear relationship. The closer r is to -1or +1, the closer the points tend to cluster about the line. Therefore, a value of r closer to -1or +1 indicates a strong degree of linear relationship. If the value of r is near 0, there will only be a very weak linear relationship.

Level of Abstraction of Underlying Concept

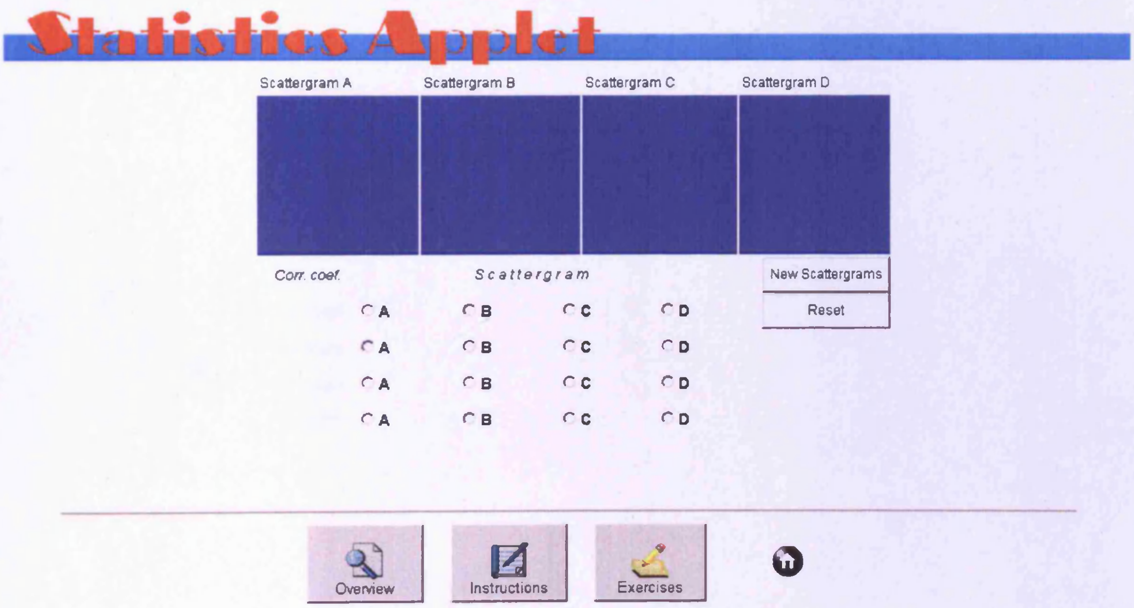
Medium. Students often find it difficult to guess the degree of relationship. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of linear relationship between two variables. In designing this applet, a few one-click buttons were deployed to generate immediate visualization and feedback. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how determine the strength of linear relationship between two variables.

Objective

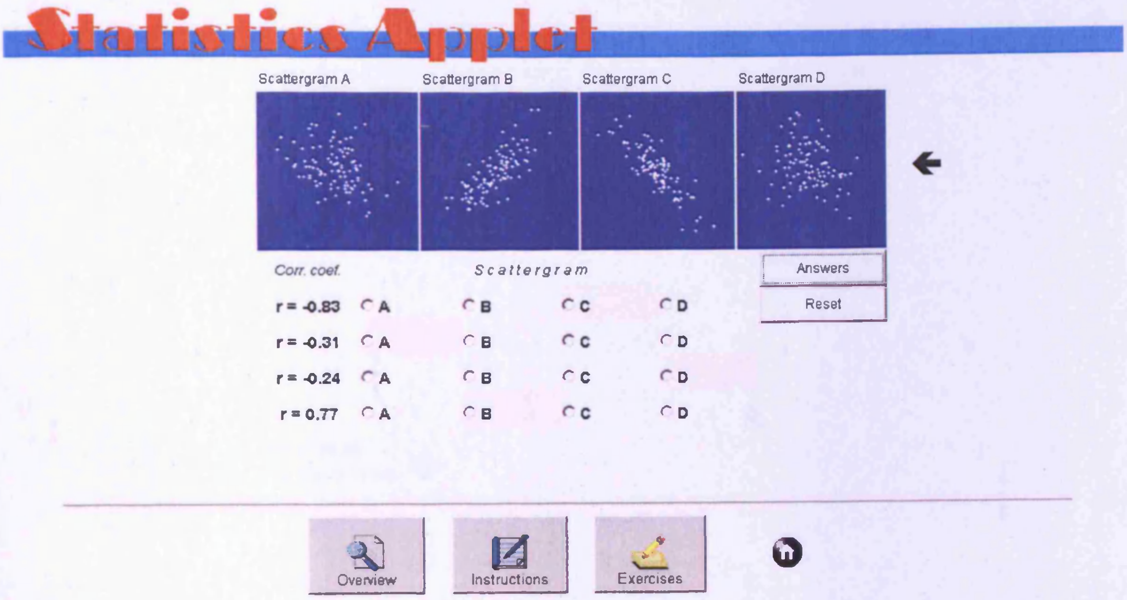
This applet is designed to show the relationships between the appearance of a scattergram and the value of the correlation coefficient. Scattergrams are useful for seeing relationships between variables.

Instructions

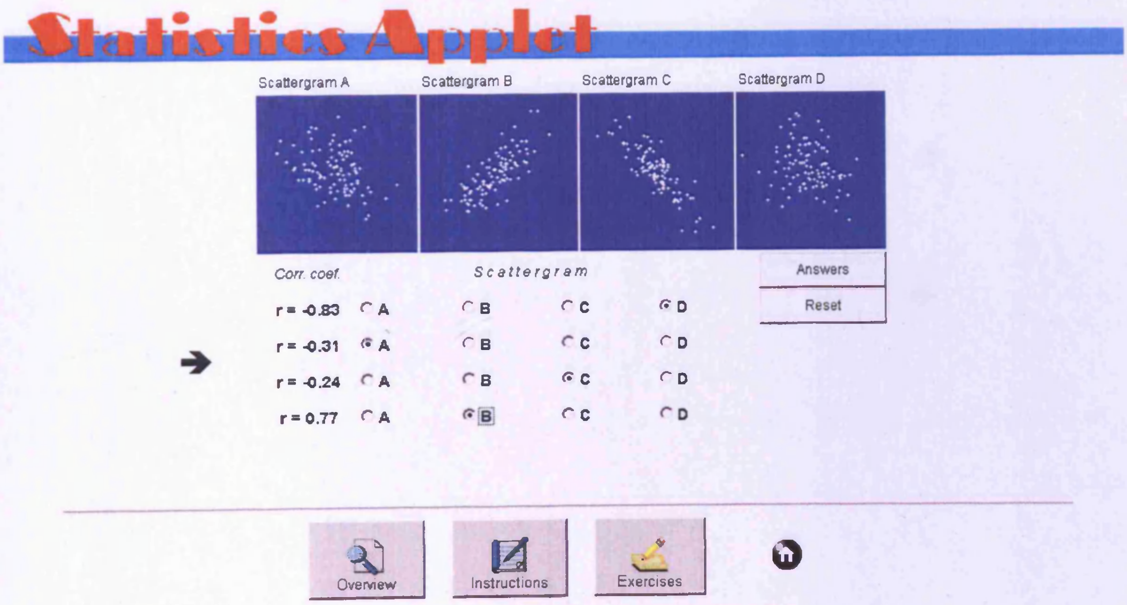
When the applet is loaded, the opening screen will appear as:



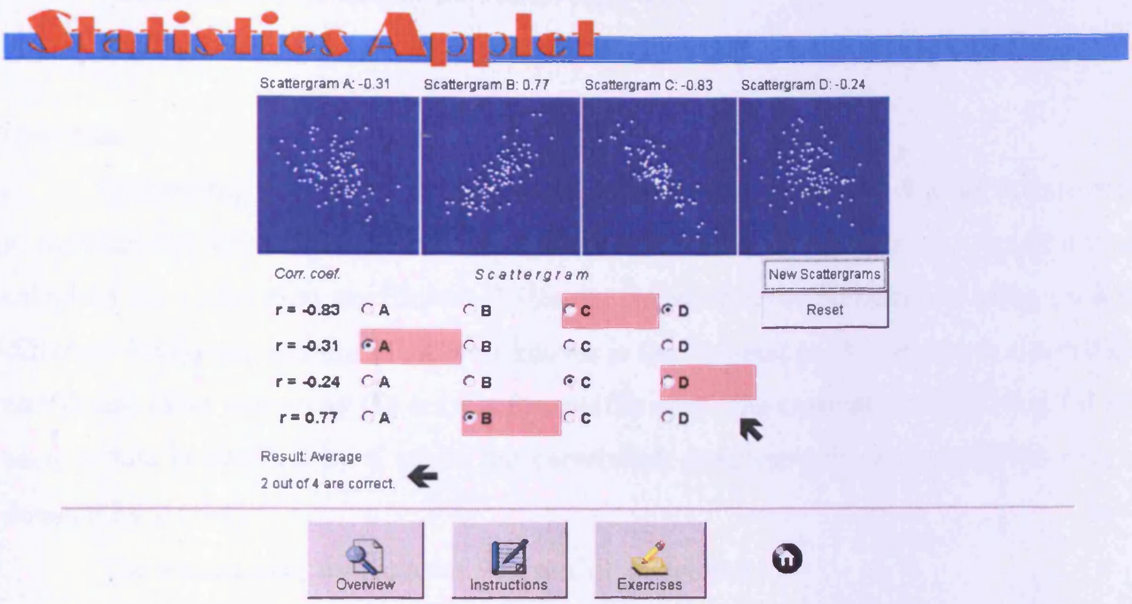
1. Press the “New Scattergrams” button. Four scattergrams should appear.



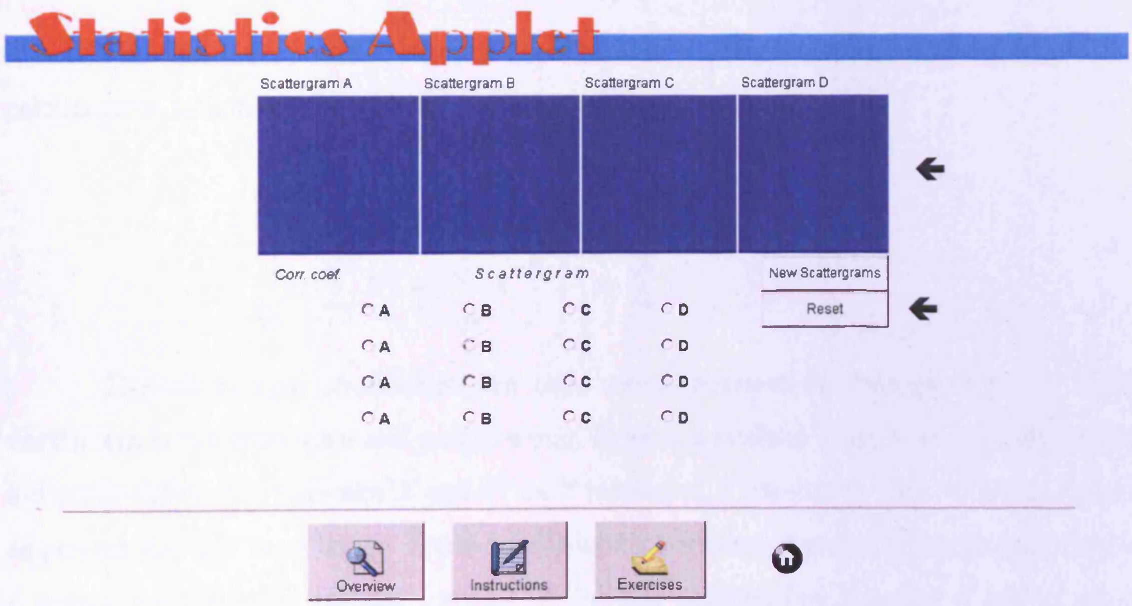
2. Match the scattergrams with the correlations at the bottom left.



3. Press the "Answers" button to check the answer.



4. Press the "Reset" button to start over again.



(ix) Correlation 2 Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/Correlation2/Correlation2.html

Overview

Interpreting correlation using a scattergram can be subjective. A more precise way to measure the direction and strength of a linear relationship between two variables is to calculate the correlation coefficient. Different correlation coefficients are being used in different situations, but the most well-known is the Pearson product-moment correlation coefficient (also known as the correlation coefficient). The correlation coefficient for the sample data is denoted by r, while the correlation coefficient for the population data is denoted by ρ (rho).

The definitional formula for Pearson's r is defined as:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})\cdot(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \cdot \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

The computational formula for Pearson's r, which generally simplify the calculations, is defined as:

$$r = \frac{n\cdot\sum_{i=1}^{n}X_iY_i - \sum_{i=1}^{n}X_i \cdot \sum_{i=1}^{n}Y_i}{\sqrt{\left[n\cdot\sum_{i=1}^{n}X_i^2 - \left(\sum_{i=1}^{n}X_i\right)^2\right]\cdot\left[n\cdot\sum_{i=1}^{n}Y_i^2 - \left(\sum_{i=1}^{n}Y_i\right)^2\right]}}$$

The correlation coefficient can take values between -1 through 0 to +1. If the coefficient is between zero and positive one, there is a positive correlation (which implies a direct relationship between X and Y: as X increases, Y increases) with +1 being known as perfect positive correlation. If the coefficient is between zero and negative one, there is a negative correlation (which implies an inverse relationship between X and Y: as X increases, Y decreases), with -1 being known as perfect negative correlation. A correlation of zero means there is no linear relationship. The closer r is to -1or +1, the closer the points tend to cluster about the line. Therefore, a value of r closer to -1or +1 indicates a strong degree of linear relationship. If the value of r is near 0, there will only be a very weak linear relationship.

Table 2 below summarizes the various strengths:

Table 2: *The Strength of a Linear Relationship*

	Computed value of r	Comment on the strength
	0	No correlation
Positive Correlation	1	Perfect positive correlation
	$0 < r < 0.3$	Weak positive correlation
	$0.3 \leq r \leq 0.7$	Moderate positive correlation
	$0.7 < r < 1$	Strong positive correlation
Negative Correlation	-1	Perfect negative correlation
	$-0.3 < r < 0$	Weak negative correlation
	$-0.7 \leq r \leq -0.3$	Moderate negative correlation
	$-1 < r < -0.7$	Strong negative correlation

The square of the correlation coefficient is called the coefficient of determination, denoted by r^2. The coefficient of determination, which lies between 0 and 1, gives the proportion of the variability in the dependent variable (Y) that is accounted for, or explained by, the independent variable (X). For instance, if the correlation coefficient is $r = 0.82$, then the coefficient of determination is $r^2 = (0.82)^2 = 0.6724$. This means that 67.24% of the variability in Y is explained by X (i.e., by the linear relationship). The remaining 32.76% of the variability is unexplained. Perhaps this portion of the variation is due to chance or other variables not considered.

The magnitude of the coefficient of determination is smaller than that of the correlation coefficient. For this reason, it is preferred by many statisticians. That is, it is a more conservative measure of the relationship between two variables. To put it another way, the correlation coefficient tends to overstate the association between two variables. A correlation coefficient of 0.72, for example, would suggest a fairly strong relationship between two variables. Squaring r, however, gives a coefficient of determination of 0.5184, which is a somewhat smaller value.

Level of Abstraction of Underlying Concept

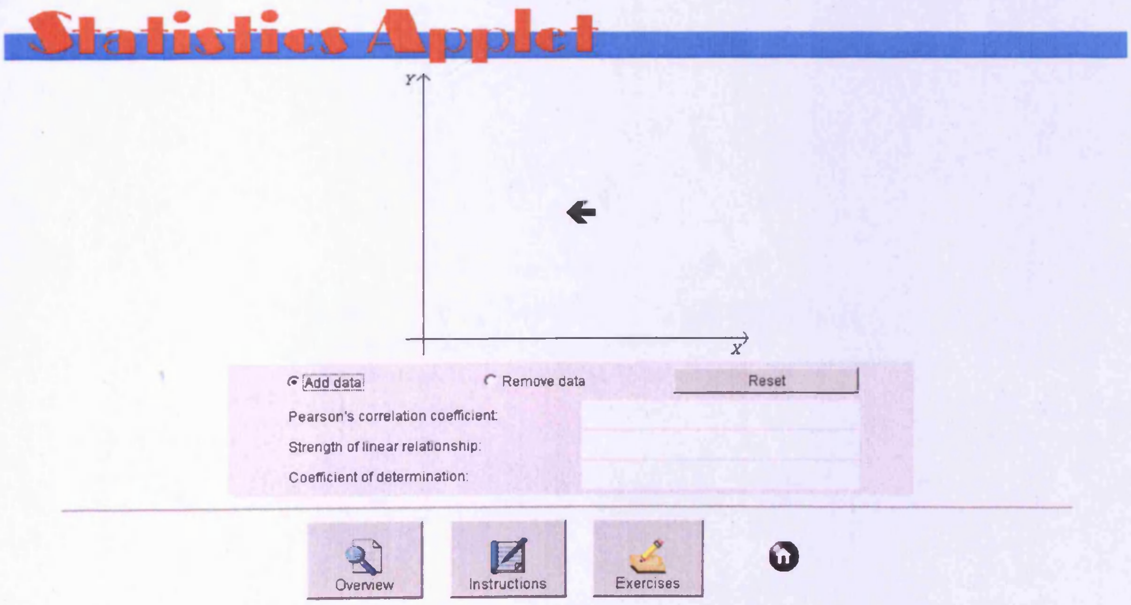
Medium. Students are often confused with the concept of coefficient of determination. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of calculating coefficients of correlation and determination. In designing this applet, radio buttons and one-click data point insertion/deletion were deployed to generate immediate visualization and numerical output. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate the two coefficients.

Objective

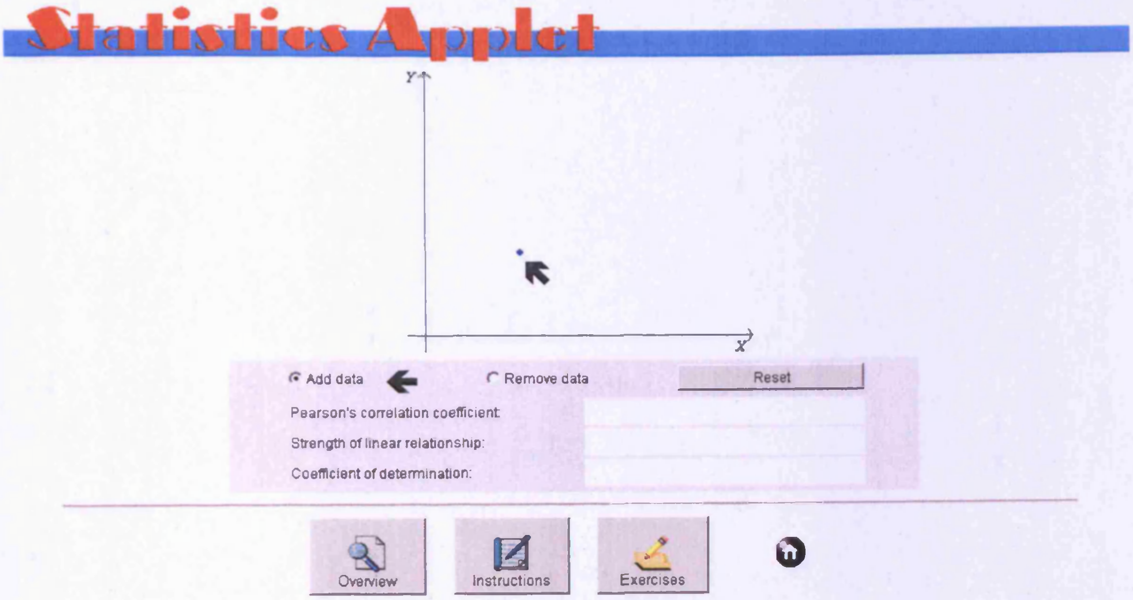
This applet is designed to show the relationships between the appearance of a scattergram and the value of the correlation coefficient. The correlation coefficient will be calculated. Correlation coefficient is useful for measuring the degree of linear relationship between two variables. Comment will be made on the strength of the linear relationship. In addition, the coefficient of determination will also be computed. The coefficient of determination is useful for interpreting the degree of linear relationship in more familiar terms, so that one can make a judgment whether a useful relationship between the x and y values exists.

Instructions

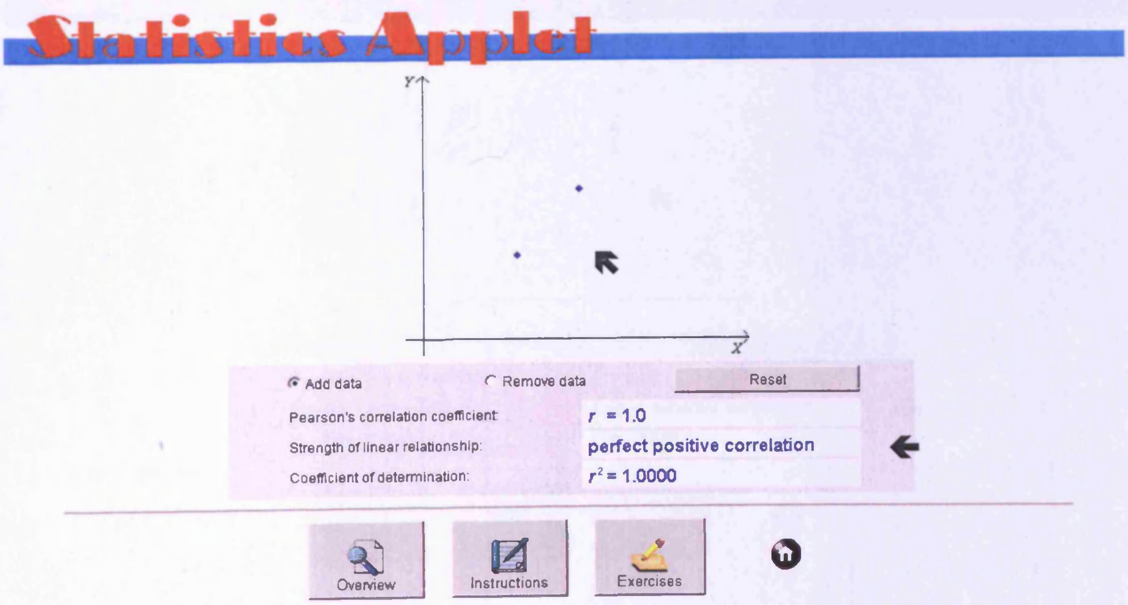
1. When the applet begins, the canvas is blank.



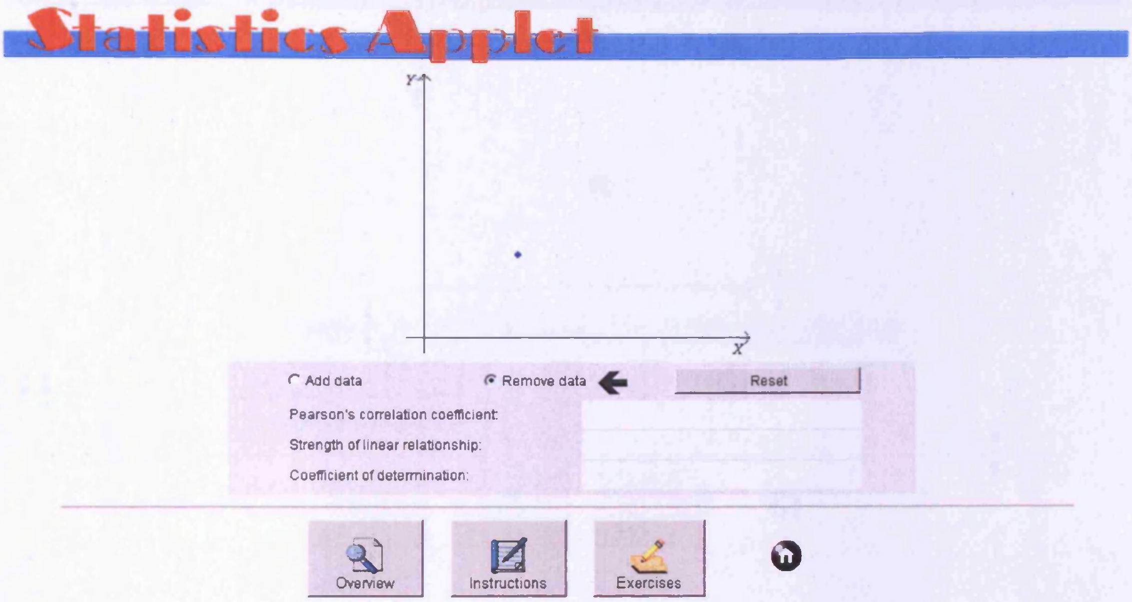
2. Use the mouse and click on the canvas. If the "Add data" radio button is selected (default), a new point (blue dot) will be added to the graph.



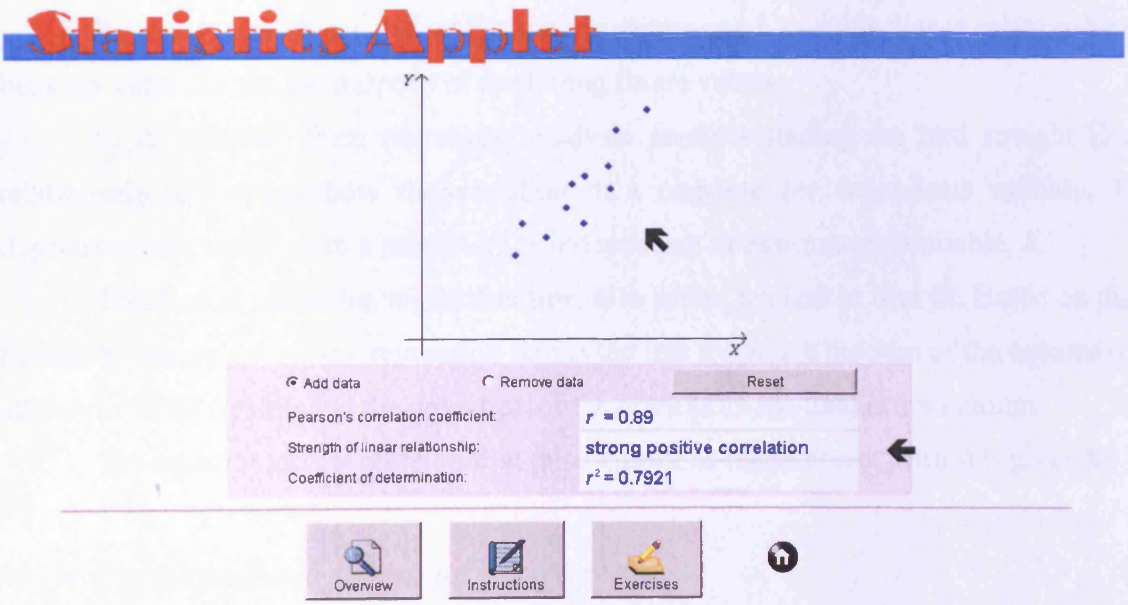
3. After two points are added, the Pearson's correlation coefficient (r) and the coefficient of determination (r^2) will be calculated. Comment on the strength of the linear relationship will also be displayed.



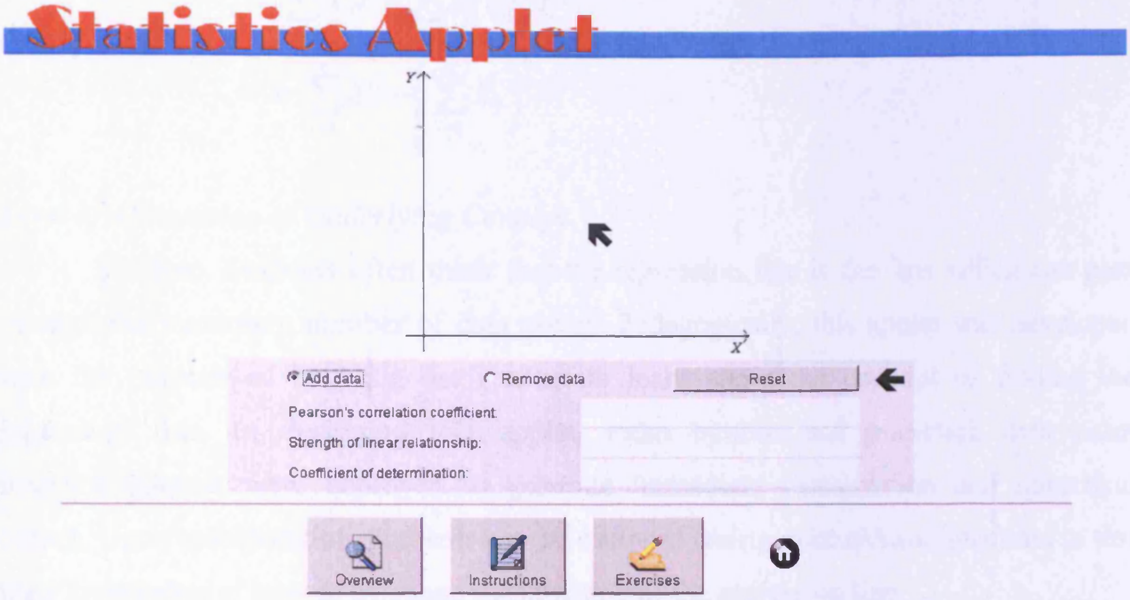
4. To remove points, select the "Remove data" radio button and use the mouse to click on the points you would like to remove from the data set.



5. As each point is added or removed, the Pearson's correlation coefficient, the coefficient of determination, and the comment on the strength of the linear relationship will be dynamically updated.



6. Press the "Reset" button to start over again.



(x) Regression Applet

The applet is available at the following URL:

http://csp.ipm.edu.mo/teachers/edmund/statistics/Regression/Regression.html

Overview

Regression analysis is a statistical technique used to study linear relationships between variables for the purpose of predicting future values.

In its simplest form regression analysis involves finding the best straight line relationship to explain how the variation in a response (or dependent) variable, Y, depends on the variation in a predictor (or independent or explanatory) variable, X.

This line is called the regression line, also called the line of best fit. Based on the method of least squares, the regression line is the line for which the sum of the squares of all the residuals (residual is the deviation of the point from the line) is a minimum.

The equation of a regression line (also known as regression equation) is given by

$$\hat{y} = ax + b$$

where $\hat{y}$ is the predicted y-value for a given x-value.

The slope a and y-intercept b are given by

$$a = \frac{n \cdot \sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \cdot \sum_{i=1}^{n} Y_i}{n \cdot \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i \right)^2} \quad \text{and} \quad b = \overline{Y} - a \cdot \overline{X}$$

Level of Abstraction of Underlying Concept

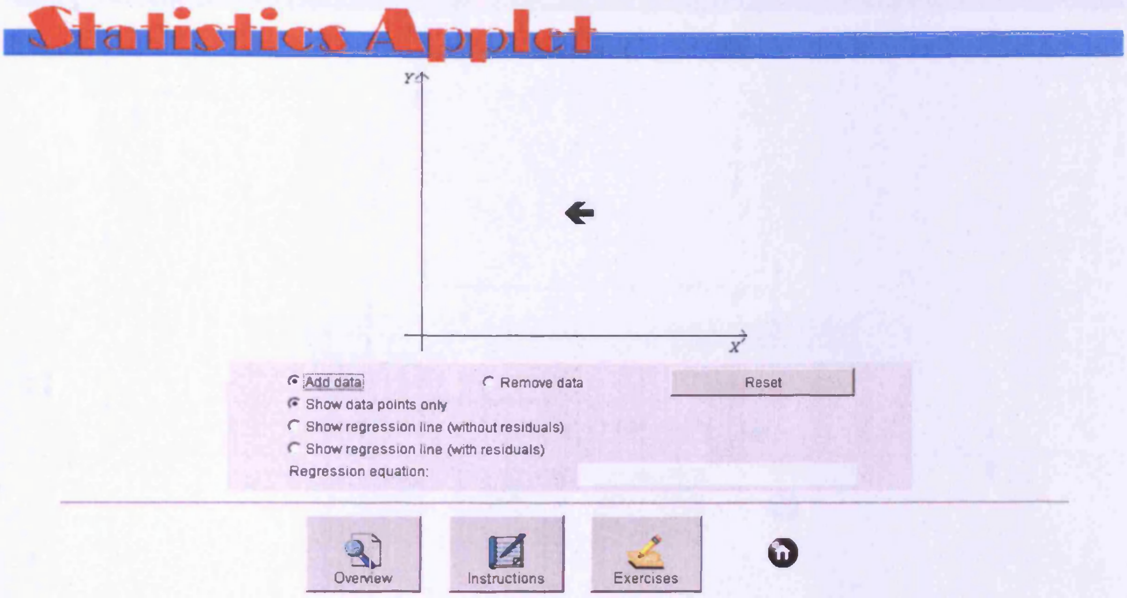
Medium. Students often think that the regression line is the line which can pass through the maximum number of data points. Pedagogically, this applet was developed with the purpose of enabling the student to learn about the concept of finding the regression line. In designing this applet, radio buttons and one-click data point insertion/deletion were deployed to generate immediate visualization and numerical output. Upon manipulation, students can be assessed (using quizzes/examinations) to test their knowledge of how to calculate the equation of the regression line.

Objective

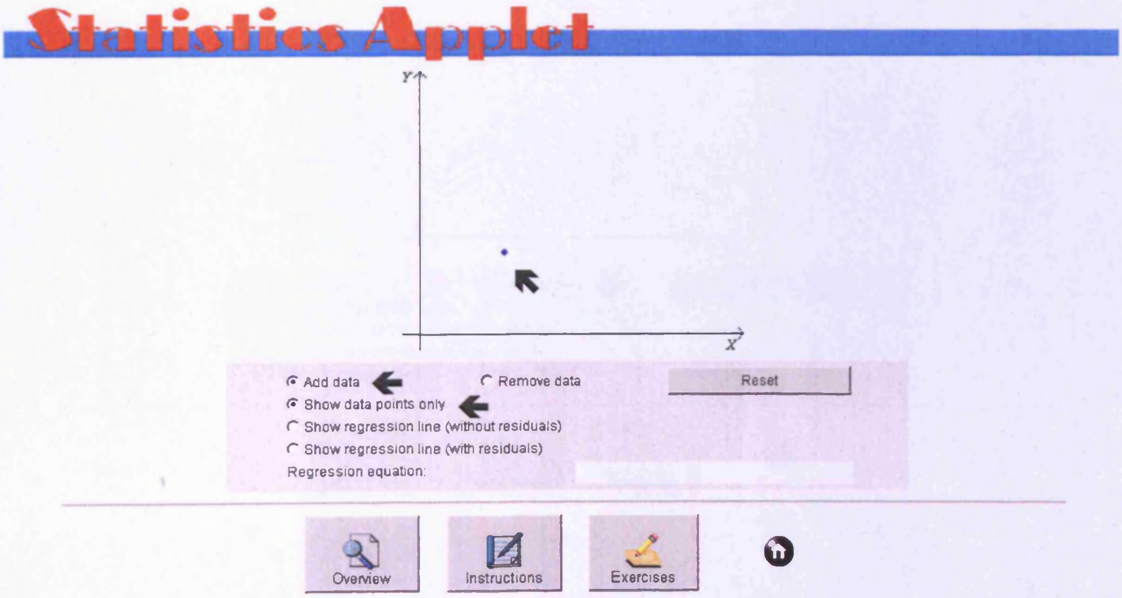
This applet is designed to demonstrate the principles of simple linear regression analysis and least squares analysis (the process by which a regression model is developed based on calculus techniques that attempt to produce a minimum sum of the squared error values). In addition, the equation of the regression line will be calculated. Regression lines are very useful for making predictions.

Instructions

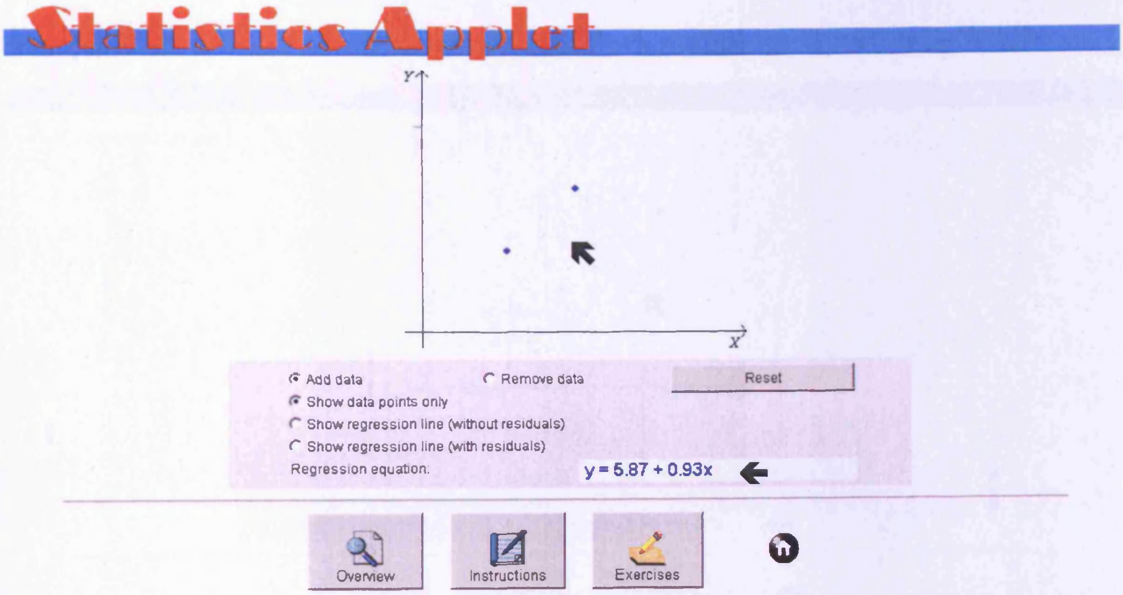
1. When the applet begins, the canvas is blank.



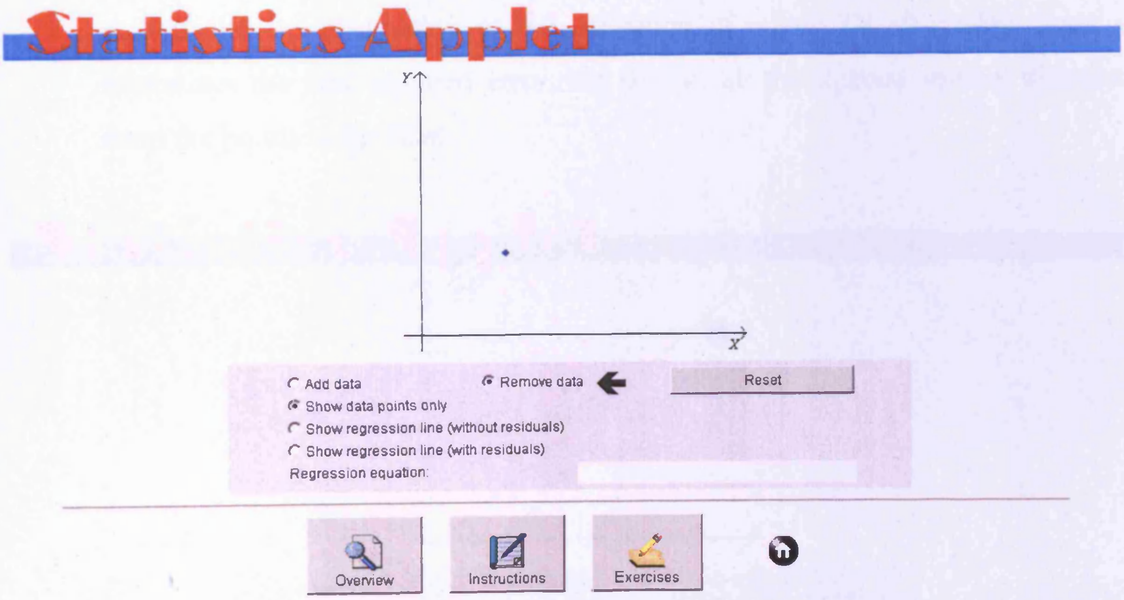
2. Use the mouse and click on the canvas. If the "Add data" and "Show data points only" radio buttons are selected (default), a new point (blue dot) will be added to the graph.



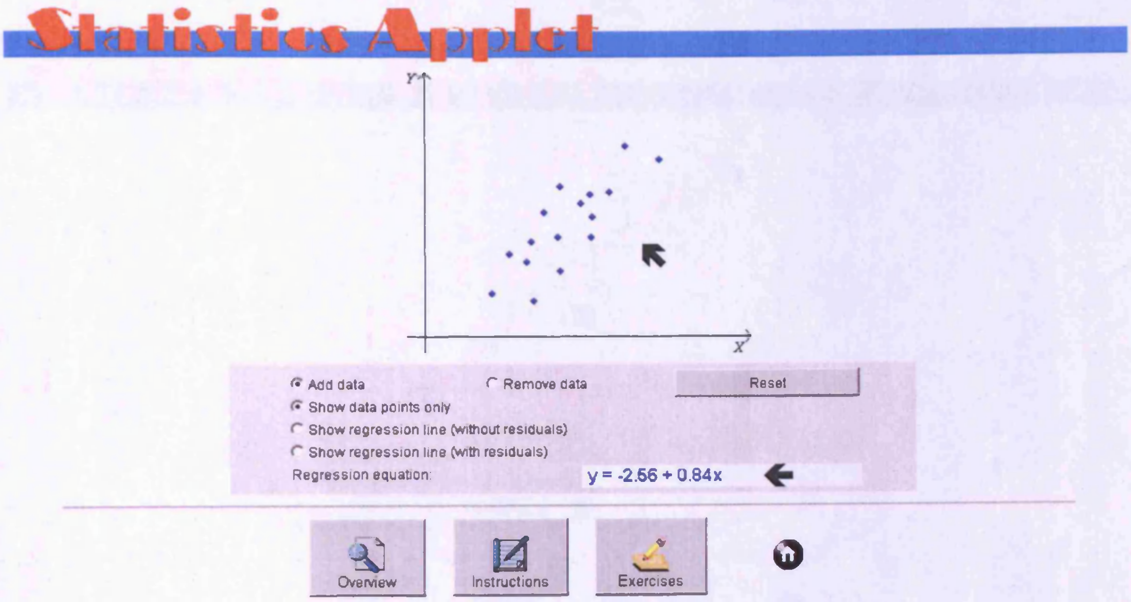
3. After two points are added, the regression equation of the data set is computed.



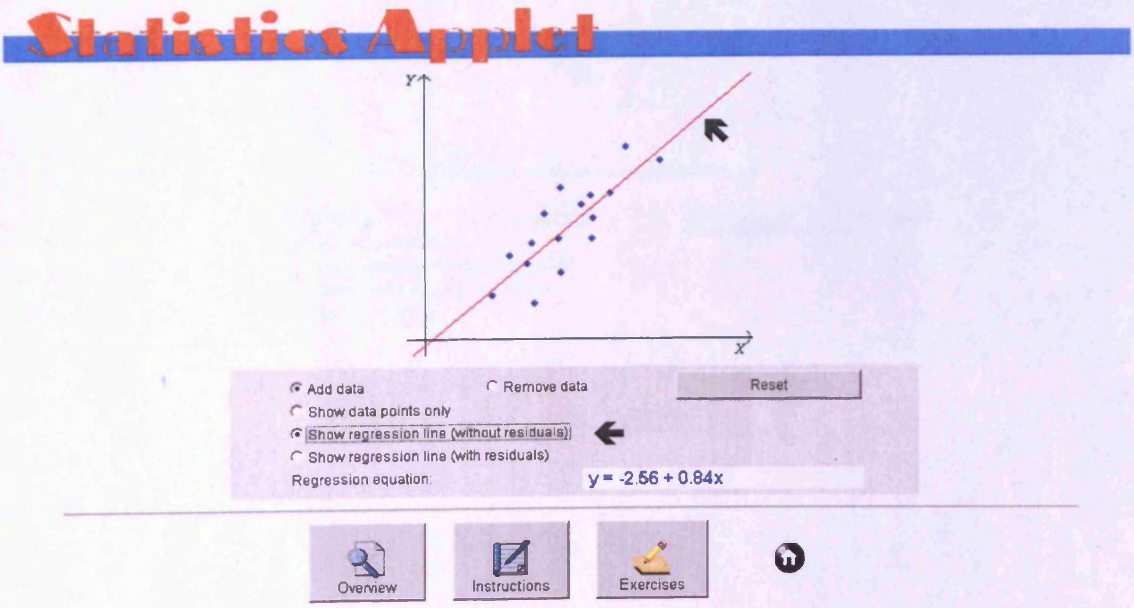
4. To remove points, select the “Remove data” radio button and use the mouse to click on the points you would like to remove from the data set.



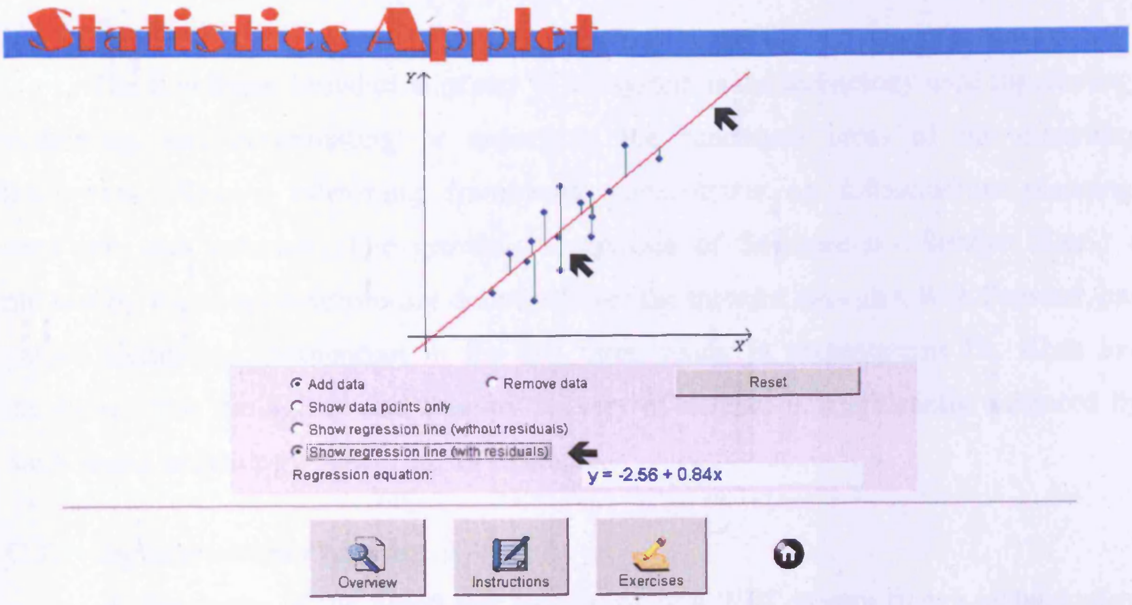
5. As each point is added or removed, the equation of the regression line will be dynamically updated.



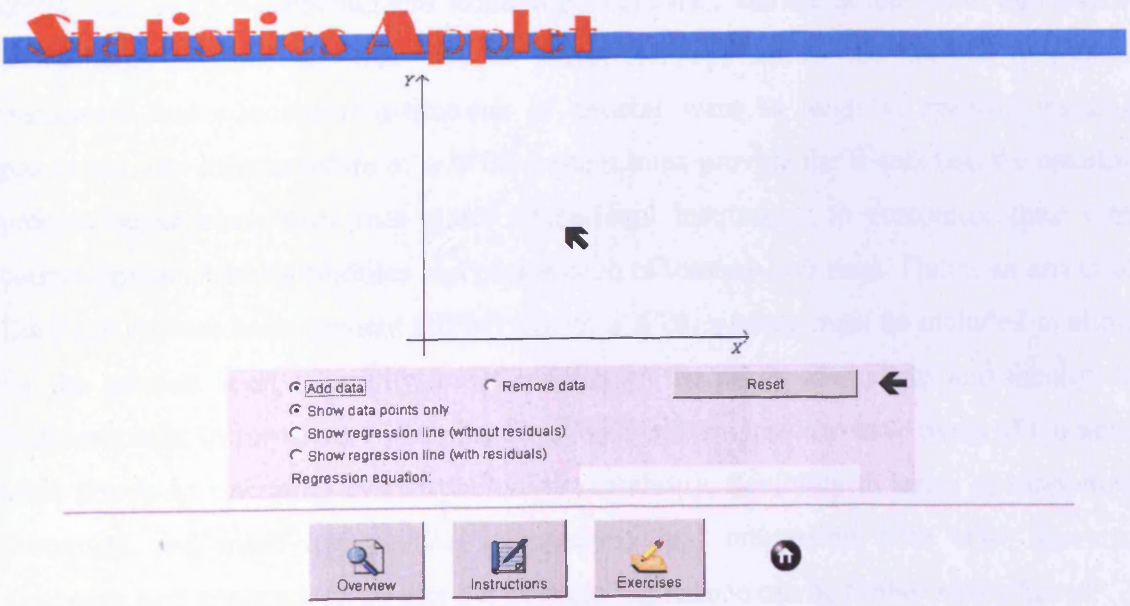
6. If the “Show regression line (without residuals)” radio button is selected, a red line will be displayed on the graph. The red line is the regression line, the best straight-line approximation to the collection of points. Of all straight lines, it minimizes the total squared error, the sum of all the squared vertical distances from the points to the line.



7. If the "Show regression line (with residuals)" radio button is selected, the regression line (red line) together with the residuals (yellow dashed line) will be displayed on the graph.



8. Press the "Reset" button to start over again.



APPENDIX D:

DIMENSIONS (MACRO-END) OF KHAN'S WBL FRAMEWORK

The macro-end dimensions are: technological, management, resource support, ethical, and institutional.

C.1 Technological

The functional foundation of any WBL system is the technology used for creating, sustaining, and accentuating or enhancing the functional areas of the e-learning framework. Khan's e-learning framework concentrates on infrastructure planning, hardware and software. The growing acceptance of Software-as-a-Service (SaaS) a method by which applications are delivered over the Internet through a Web Browser, has gained significant momentum in the last three years. In presentations Dr. Khan has mentioned that the agility and time-to-delivery of courses is significantly enhanced by SaaS-based technology platforms for example.

C.1.1 *Infrastructure Planning*

At the centre of the functional foundation of a WBL system from a technological perspective is its infrastructure. This includes the foundational elements necessary to create a smoothly running WBL system, including integration adapters and connectors, compliance to both reporting and technology standards, and the definition of application components or modules that can be selectively applied to the specific processes instructors and education institutions in general want to align to specific learning processes. The infrastructure of a WBL system must provide the foundation for creating process-based workflows that allow educational institutions to customize their own course-driven learning modules and progression of lessons over time. This is an aspect of Business Process Management (BPM) that in a WBL system, must be included to allow for the greatest level of agility and flexibility to the needs of students and faculty. In many respects, infrastructure planning for a WBL system needs to have many of the same attributes as an operating system including scalability, flexibility in terms of supporting processes, and most importantly, connectivity and integration with other systems, databases, and applications so that the learning experience can be further strengthened.

C.1.2 *Hardware*

The hardware prerequisites necessary for enabling an infrastructure must further support the design and scalability objectives of the broader WBL system. This specifically refers to the need to align the best possible hardware components available with the prerequisites for the infrastructure computing platform that is going to be used. An example of this would be the decision to use Microsoft SharePoint Services to create a WBL system. SharePoint Services requires an Intel-based personal computer or server with at least 1GB of free disk space and 2GB of free memory. These prerequisites of the hardware platform to support the infrastructure is what Khan was referring to when he added this component as part of the Methods and Strategies section of the Pedagogical Dimension of the framework. As the infrastructure platform is often required to integrate with other software components, part of the hardware perquisites is also in the area of network integration support including support for broadband Internet and support of the TCP/IP networking standard.

C.1.3 *Software*

The infrastructure platform chosen for the development of a WBL system during the planning phase needs to also support the many variations in software applications that are necessary for ensuring learning objectives are met. Infrastructure planning needs to include the selection of a software infrastructure platform that also allow for agility in the defining of workflows that learning institutions and more specifically, educators, will use in defining the sequence by which courses are taught. The essence of the ability of any WBL system then to be agile and capable of responding to the changing needs of educators is in the software applications, their relative levels of integration to one another and the infrastructure base, and also the integration into a more process-centric approach to defining learning workflows. At their most basic level, these software applications that must be capable of being integrated into the infrastructure platform include forms-based e-mail, support for Internet Chat, support for common word processing, graphics, spreadsheet and database applications in addition to support for collaboration tools including digital blackboards and on-line presentation tools.

C.2 Management

The Management Dimension of Khan's e-learning framework concentrates on two points, maintenance of the learning environment, and distribution of information. In maintaining the learning environment, there needs to a scalable and customizable set of applications and tools for completing the administration, maintenance, and operation of the WBL system. Khan's perspective on this specific point also concentrates on ensuring the applications and on-line lesson content are agile enough to reflect the changing state of knowledge being studied. This section covers both points of the Management Dimension, beginning with an overview of e-learning maintenance, followed by a discussion of e-learning content development.

C.2.1 *Maintenance of the Learning Environment*

Agility is a key design objective of any WBL system to ensure it can be maintained effectively while at the same time being robust enough in design to allow for greater additions of content and knowledge, encapsulated as lessons and learning tasks, over time. Maintenance of the learning environment needs to encompass the budgetary considerations of keeping the system up and running, addition of administrative tools and the learning of new processes to ensure the WBL system stays agile enough to respond to changing knowledge needs, and the development of modules, both in the form of customized HTML and JavaScript programming, to more precisely align with the changing learning needs of students.

C.2.2 *Distribution of Information*

Khan's e-learning framework, when viewed as taxonomy of system components, resembles an enterprise content management (ECM) system. In terms of the distribution of information throughout a WBL system, the ECM components work together to organize and index the knowledge that serves as the foundation of learning modules and course outlines. From the most statically-used information such as syllabus listings and contact information to the more dynamic content of abstract concepts that require intensive graphical support, the reliance on content management techniques within a WBL system is clear. The development of an ECM that can act as a catalyst for managing the many forms of content is critical for the agility, scalability and ongoing use of a WBL system in staying aligned with students' learning needs.

C.3 Resource Support

Implicit in much of what Khan has written about regarding his e-learning framework is the concept of high levels of content, process, and knowledge integration. The Resource Support Dimension is one of the critical building blocks of this concept of tight integration across the Khan e-learning framework. Khan has defined On-line Support and Resources as the two critical areas of the Resource Support Dimension of his e-learning framework.

C.3.1 *On-line Support*

Inherent in the design of a WBL system is the need to support students on a 24/7 basis, as the time flexibility of learning when their schedules make time available is one of the more popular reasons for enrolling in e-learning courses. This specific point as part of the Resource Support Dimension includes instructional/counseling support and technical support. Both of these components of the on-line support point are briefly described here.

Instructional/Counseling Support. Distance learners are more goal-oriented and therefore more willing to make sacrifices to accomplish their learning objectives. Motivation to complete an on-line course and participate in on-line learning varies by student. As a result of the "always on" nature of on-line learning, it is imperative that instructional support and counseling be also available on a 24/7 basis. The use of web applications that can guide students through answers to their questions requires the use of on-line technologies that are collectively called guided knowledge management systems. The development of on-line counseling applications using these guided techniques is equally effective. The objective of these on-line guided knowledge systems is to provide for assistance and guidance to students on a 24/7 basis. Hart (1999) points to the need to provide distance learners with on-line tools that allow them to learn how to use technologies in addition to internalizing the key concepts of the course, with each task ultimately supporting the other in the fulfillment of distance-based education programme objectives. Palloff and Pratt (1999) have also observed that effective time management is also critical as an attribute for on-line learners. Campbell (1999) provides a series of insights on how to create greater levels of student adoption of on-line resources through their participation in the process.

Technical Support. Giving students the necessary on-line tools and Web-based diagnostic tools to solve technical support problems is crucial if the WBL system is to deliver the maximum level of benefit possible. Technical support needs to be organized into levels of escalation with the majority of levels available through Web-based guided applications to make sure students can get responses to their questions on when needed, regardless of the time of day.

C.3.2 *Resources*

The second point within the Resource Support Dimension is the resources are further defined by being on-line or off-line. Within this section, the delineations of each of these aspects are discussed. As any course that is based on the Khan e-learning framework requires a combination of both types of resources to successfully complete a course, each type of resource is critical for the attainment of learning objectives in a course.

On-line Resources. By definition these are course materials that are available over the Internet, and in those WBL systems that have been designed specifically for use over web browsers. The resources that are made available electronically, taken together, are the on-line resources of any WBL systems. These include documents that are easily electronically posted and downloaded for students' and instructors' use. Adobe Acrobat, Microsoft Excel, Word, and PowerPoint files, and many other formats are typically stored within On-line Resource Centres. Implicit in these Centres are search tools and content management utilities that provide students with navigational aids to find the information they need.

Off-line Resources. By definition these are resources that are printed and sent to students and instructors in hardcopy form. Increasingly off-line resources are also being digitized and stored on-line to ensure they are available on an on-demand basis. Historically off-line resources include books, journals, magazines, newspapers, reference materials and hard copies of presentations.

C.4 Ethical

The Ethical Dimension of Khan's e-learning framework is a catalyst of collaboration, in addition to defining social, pedagogical and managerial rules of conduct for the use of the e-learning system. Included in the Ethical Dimension of Khan's e-learning system are the points of social and political influence, cultural diversity, bias, geographical diversity, learner diversity, Digital Divide, etiquette, and legal issues. These factors are collectively discussed in this section.

C.4.1 *Social and Cultural Diversity*

There is growing recognition of the fact that the greater the diversity of students from both a social and cultural standpoint in a course, the greater the collaborative learning that takes place due to the differences in perspectives enriching the class. This occurs in both in in-class and e-learning courses as well. It is the responsibility of the WBL system designer and developers to take into account differences in both social and cultural diversity relating to the specific nations and regions of the world where the WBL system will be used. There are significant differences between how students from varying social and cultural backgrounds perceive content, navigation, use of graphical expressions, in addition to wide variations in expectations relating to ergonomics and navigation of WBL systems. What's needed is an appreciation of how social and cultural diversity needs to drive the development of WBL systems that are applicable across a wide spectrum of cultural requirements.

C.4.2 *Geographical Diversity*

Khan's e-learning framework has many structural concepts and interlinking attributes to ensure there is a high level of collaboration, communication, and trust created both between students themselves and between students and instructors. Regardless of physical distance and the inherent geographical diversity inherent in e-learning programmes, Khan's e-learning framework concentrates on minimizing and eliminating ethnocentrism and geographic bias. Arguably the ability to define, develop, launch and perfect an e-learning system is directly related to ensuring a high level of geographic diversity in both the content and design of the system itself. The process by which systems are made more to reflect the unique needs of a given geographic area is called localization. It is a critical concept that needs to be applied to the development of WBL systems.

C.4.3 *Learner Diversity*

One of Khan's design objectives in creating the e-learning framework is to create a system architecture that can scale for variations in learners' diversity from a cultural, skill, learning ability, and geographic orientation. In the context of this specific point of the Ethical Dimension, learner diversity focuses on taking down the barriers to WBL system content, navigation and overall use to make the entire learning value of the system accessible to a wide diversity of users. Taking into account the wide diversity of learners from many different races, colours, and creeds, WBL system designers need to specifically look at their system development and ongoing content creation from the vantage point of each learner and their unique diversity needs. This is best accomplished by concentrating on the unique unmet needs of each audience of learners, taking into account the unique requirements of their diverse backgrounds.

C.4.4 *Information Accessibility or the Digital Divide*

For any WBL system to be effective it must be specifically designed to bridge the gap between the most impoverished students to those that have means to gain broadband access easily. The Digital Divide that exists in practically every nation in the world is heavily correlated at the low end with poverty-level incomes and a complete lack of infrastructure that can support Internet access over dial-up connection. In more westernized nations where broadband infrastructure is prevalent, higher speed access is commonplace. The implications for a WBL system are clear; for those in the impoverished regions of the world where even a dial-up connection is a luxury, the interface, applications and system navigational functions must be efficiently enough designed to allow for quick response even on the slowest of dial-up lines.

C.4.5 *Etiquette*

Social networking is redefining on-line etiquette, and with it, the behaviour of students on-line within chat rooms for their courses in addition to how they interact with each other on a daily basis. As the Internet is increasingly a source of research concerning new job applicants, students need to be reminded that once a comment is on the Internet, chances are it will stay there for a very long time. WBL systems need to be designed to allow for editing and retraction of comments, yet most importantly, must be designed to catch language that is inappropriate for use in on-line collaboration forums for an e-learning course.

C.4.6 *Legal Issues*

The issues of copyright infringement, plagiarism and privacy all have become escalated over the last several years, and to be effective any WBL system needs to take them into account. They are briefly discussed here.

Privacy. As has been noted in previous sections, any and all content on-line is searchable and viewable potentially by future employers of both students and instructors. Palloff and Pratt (1999) remind students that all of their content provided in course forums, chat sites, and newsgroups can and often is indexed by search engines, and is quickly available over the Web to anyone searching on a topic related to the on-line conversation, or a person's name associated with the comments.

Plagiarism. One of the most serious breaches of trust between students and instructors, plagiarism undermines the trust necessary for a course to be successful. There are many on-line applications, tools and websites for validating the work of students; it is suggested that WBL systems integrate to these sites to ensure a high level of academic ethicacy is achieved.

Copyright. The catalyst of a WBL system is the knowledge included within it. With many difference databases required often to populate a WBL system with valuable content, the issue of copyrights often arises. The use of copyrighted materials within the WBL system must be in full compliance to the laws governing where the WBL system is in use, and further, there needs to be approvals on file with the WBL system developer to ensure a high level of compliance on this legal issue.

C.5 Institutional

The Institutional Dimension of Khan's e-learning model concentrates on the points of administrative affairs, academic affairs, and student services, each of which are briefly defined in this section. These are the governance aspects of Khan's e-learning framework and centre on the need for ensuring a high level of continuing and directional leadership for how the WBL system is deployed, augmented or enhanced, and used throughout its life cycle.

C.5.1 *Administrative Affairs*

Administrative affairs as part of the Institutional Dimension concentrate on how governance and the direction of WBL system is defined from a strategic planning perspective. This specific point of in the Institutional Dimension concentrates on ensuring the entire system is well synchronized and capable of fulfilling the delivery of exceptional learning experiences to students.

C.5.2 *Academic Affairs*

As the second point in the Institutional Dimension, academic affairs concentrate on the synchronization of efforts from faculty and staff support, and instructional affairs. These two aspects of Academic Affairs are essential for further support of governance, creation, execution and fulfillment of the strategic plans of the learning institutions, and the continual alignment of WBT systems to the needs of students.

Faculty and Staff Support. The supporting infrastructure of a WBL system from a governance, leadership and management perspective need to include support for faculty and staff training and assistance, including ongoing training as well for a WBL system to be effective in the long-term. Price (1999) contends that there is a major deficiency in the initial training for faculty teaching Web-based courses, and as a result, there is a corresponding level of low performance overall for on-line courses. What is needed is an entirely new commitment to the governance, strategic planning and execution of strategies in WBL systems to enable faculty and staff enrichment and enhancement.

Instructional Affairs. The collaboration between instructors and administrators is also critical for the efficiency of a WBL system in attaining its objectives. The role of instructional affairs concentrates on the processes of instructor collaboration between themselves and administrators in attaining specific e-learning goals and objectives.

Admissions, Registration, and Payment. When the majority of students for a given course are dispersed geographically throughout the world, there is the need to automate the processes included in admissions, registration, and payment so they are globally available yet localized for the needs of individual regions. Taking into account variations in the currencies used, methods of payment, potential for employer and government reimbursement, and payment plans based on credit all must be taken into account in the design of automated systems to accomplish these tasks.

Information Technology Services. Foundational to the success of a WBL system are the underlying Information technology Services required to create a scalable, security yet agile technology platform to host the WBL system on. The attributes of accessibility, integration flexibility, scalability and security are all critical objectives in this area of WBL system development.

C.5.3 *Student Services*

Khan, in discussing the implications of his e-learning framework from a customer-centricity perspective, has often stated that the student is at the centre of the framework model, as they are the ones served by the synchronization of its components. The role of student services is critical in aligning the entire Khan e-learning framework to students' unmet needs. The aligning of all aspects of the e-learning framework to the learning needs of students is what keeps e-learning as a strategy relevant. According to Connick (1999), "Students often assume that an institution offering courses or programmes at a distance will also provide all of the essential services at a distance" (p.26), and this is a reasonable assumption as students are often expecting the learning experience to be entirely accessible on-line. The design of a WBL system therefore needs to take this expectation into account and create a specific series of design objectives in the areas defined in this section.

Orientation. Just as with off-line or in-class courses, there needs to be allowances for an orientation to be completed that covers the main topics of the course, logistics and deadlines for deliverables back and forth to the students, and the development of individualized lesson plans in the event scaffolding is included in the WBL system being developed.

Bookstore. Through the use of electronic commerce applications that can easily integrate into many of the technological platforms of WBL systems, this is a core requirement of any e-learning system. The continual work of Amazon.com with their web services in addition to support for links to their books and materials are an essential element of any e-learning platform and system.

Library Support. Critical to support both on-line and off-line versions of libraries to ensure there is a high level of responsiveness to the needs of students. This has been discussed in the Resource Support Dimension of the Khan e-learning framework as well.

Financial Aid. As there are wide variations in the availability of financial aid for students depending on their country of origin, arrangements for reimbursement from their nations or employers, and the availability of individual credit lines. A WBL system needs to take these financial factors into account in defining its workflows to ensure students can gain financial support while at the same time preserving their confidentiality and continuing to pursue their learning objectives.

Counseling. As with other aspects of using Web-based applications that guide students to technical support and automated on-line support, the same needs to be the case with counseling. The use of Web-based applications for guiding students through decisions, while also giving them the opportunity to escalate their questions regarding further degree programmes must also be considered in the design of any WBL system application for this purpose.

APPENDIX E:

LETTER OF INFORMED CONSENT

MACAU POLYTECHNIC INSTITUTE
SCHOOL OF PUBLIC ADMINISTRATION
Computer Studies Programme

September 18, 2006

Dear Student:

You are invited to participate in this research study. The following information is provided in order to help you make an informed decision whether or not to participate. If you have any questions please do not hesitate to ask.

The purpose of this study is to provide information about MMAT270 Statistics -- the first experience in the Macau Polytechnic Institute. You are invited to participate in this study because you are a student in MMAT270 Statistics.

There are no risks or discomforts associated with this research and participation in this study will not require any special time or effort on your part. The study will occur over the course of 15 weeks. The control group will receive the traditional platform based instruction of statistical concepts while the test group will receive the Java applet-based instruction. Both groups will take pre and post knowledge tests. The information gained from this research will result in an objective evaluation of MMAT270 Statistics and guide our continued development of new directions in curriculum and instruction design.

Should you choose to participate, all information you provide and all testing information will be kept strictly confidential.

You are free to decide not to participate in this study or to withdraw at any time during the study without adversely affecting your relationship with the researcher or the Macau Polytechnic Institute. Your decision will not result in any loss of benefits to which you are otherwise entitled.

You may ask any questions concerning the research either before agreeing to participate or during the course of the research.

I have been informed of the nature of this evaluation and consent to participation in this study.

Student's Printed Name	Student I.D.
Student's Signature	Date

APPENDIX F:

DEMOGRAPHIC INFORMATION FORM

Student I.D.: __________

Please answer each item below by marking the answer that MOST agrees with your response. Make sure erasures are complete because multiple responses are not allowed. When finished with evaluation, please do not fold or staple. Thank you for your cooperation.

1. What is your GPA? __________

2. What is your age (in years)? __________

3. How comfortable are you with computers?

   _____ Very Uncomfortable _____ Uncomfortable

   _____ Uncertain _____ Comfortable

   _____ Very Comfortable

4. What is your gender? _____ MALE _____ FEMALE

5. How much familiarity do you believe you have with statistics?

   _____ None _____ Only a Little

   _____ Some _____ A Considerable Amount

   _____ A Great Deal

APPENDIX G:

ATTITUDINAL EVALUATION FORM (PRE-INSTRUCTION)

PRE-INSTRUCTION QUESTIONNAIRE

Student I.D.: __________

Please answer each item below by marking the answer that MOST agrees with your response. Make sure erasures are complete because multiple responses are not allowed. When finished with evaluation, please do not fold or staple. Thank you for your cooperation.

Question	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
1. While taking applet-based instruction I will feel challenged to do my best.	☐	☐	☐	☐	☐
2. I will be concerned that I might not understand the material.	☐	☐	☐	☐	☐
	All of the Time	Most of the Time	Some of the Time	Only Occasionally	Never
3. I will feel isolated and alone while taking applet-based instruction.	☐	☐	☐	☐	☐
4. I will find myself just trying to get through the material rather than concentrating on learning.	☐	☐	☐	☐	☐
	Quite Often	Often	Occasionally	Seldom	Very Seldom

5. Before I am told, I will know whether my answer is correct or not.	☐	☐	☐	☐	☐
6. For questions I am not sure about I will probably guess at the answers.	☐	☐	☐	☐	☐
	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
7. I will be interested in trying to find out more about the subject matter when some of the study material is going to be delivered applet-based instruction.	☐	☐	☐	☐	☐
8. Applet-based instruction makes me feel like I could work at my own pace.	☐	☐	☐	☐	☐
9. Applet-based instruction will make the learning too mechanical.	☐	☐	☐	☐	☐
10. Applet-based instruction is an inefficient use of the student's time.	☐	☐	☐	☐	☐
	Quite Often	Often	Occasionally	Seldom	Very Seldom
11. While on applet-based instruction I expect to encounter mechanical malfunctions.	☐	☐	☐	☐	☐
	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

12. Applet-based instruction will make it possible for me to learn quickly.	☐	☐	☐	☐	☐
13. I will feel frustrated by the applet-based instruction situation.	☐	☐	☐	☐	☐
14. The applet-based instruction approach is inflexible.	☐	☐	☐	☐	☐
15. Applet-based instruction would make otherwise interesting material boring.	☐	☐	☐	☐	☐
16. In view of the effort I will put into it, I will be satisfied with what I will learn while taking applet-based instruction.	☐	☐	☐	☐	☐
17. In view of the amount I will learn, I would say applet-based instruction is superior to traditional instruction.	☐	☐	☐	☐	☐
18. I would prefer taking a course by applet-based instruction more than by traditional instruction.	☐	☐	☐	☐	☐
19. Applet-based instruction will be too fast.	☐	☐	☐	☐	☐
20. Applet-based instruction will be boring.	☐	☐	☐	☐	☐

APPENDIX H:

ATTITUDINAL EVALUATION FORM (POST-INSTRUCTION)

Student I.D.: __________

Please answer each item below by marking the answer that MOST agrees with your response. Make sure erasures are complete because multiple responses are not allowed. When finished with evaluation, please do not fold or staple. Thank you for your cooperation.

Question	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
1. While taking applet-based instruction I felt challenged to do my best.	☐	☐	☐	☐	☐
2. I was concerned that I might not be understanding the material.	☐	☐	☐	☐	☐
	All of the Time	Most of the Time	Some of the Time	Only Occasionally	Never
3. I felt isolated and alone while taking applet-based instruction.	☐	☐	☐	☐	☐
4. I found myself just trying to get through the material rather than concentrating on learning.	☐	☐	☐	☐	☐
	Quite Often	Often	Occasionally	Seldom	Very Seldom
5. Before I was told, I knew whether my answer was correct or not.	☐	☐	☐	☐	☐

6. For questions I was not sure about I guessed at the answers.	☐	☐	☐	☐	☐
	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
7. I am interested in trying to find out more about the subject matter when some of the study material was delivered applet-based instruction.	☐	☐	☐	☐	☐
8. Applet-based instruction made me feel like I had the chance to work at my own pace.	☐	☐	☐	☐	☐
9. Applet-based instruction makes the learning too mechanical.	☐	☐	☐	☐	☐
10. Applet-based instruction is an inefficient use of the student's time.	☐	☐	☐	☐	☐
	Quite Often	Often	Occasionally	Seldom	Very Seldom
11. While on applet-based instruction I have encountered mechanical malfunctions.	☐	☐	☐	☐	☐
	Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree
12. Applet-based instruction made it possible for me to learn quickly.	☐	☐	☐	☐	☐

13. I felt frustrated by the applet-based instruction situation.	☐	☐	☐	☐	☐
14. The applet-based instruction approach is inflexible.	☐	☐	☐	☐	☐
15. Applet-based instruction would make otherwise interesting material boring.	☐	☐	☐	☐	☐
16. In view of the effort I put into it, I was satisfied with what I learned while taking applet-based instruction.	☐	☐	☐	☐	☐
17. In view of the amount I learned, I would say applet-based instruction is superior to traditional instruction.	☐	☐	☐	☐	☐
18. I would prefer taking a course by applet-based instruction more than by traditional instruction.	☐	☐	☐	☐	☐
19. Applet-based instruction is too fast.	☐	☐	☐	☐	☐
20. Applet-based instruction is boring.	☐	☐	☐	☐	☐

APPENDIX I:

COURSE AND INSTRUCTOR EVALUATION FORM

Student I.D.: __________

Please rate the level of agreement using the following scale:

① = Strongly Disagree

② = Disagree

③ = Neutral

④ = Agree

⑤ = Strongly Agree

Please check one for each question.

Question	Rating
1. The instructor was well prepared and organized.	① ② ③ ④ ⑤
2. The course was well organized and designed.	① ② ③ ④ ⑤
3. Students' range of knowledge and skills of statistics was greatly enhanced within this course.	① ② ③ ④ ⑤
4. Students were informed of progress in meeting course goals.	① ② ③ ④ ⑤
5. The instructor was effective.	① ② ③ ④ ⑤
6. Course materials were relevant and meaningful.	① ② ③ ④ ⑤
7. Presentation of the topic was useful.	① ② ③ ④ ⑤
8. Clear explanation of statistical concepts.	① ② ③ ④ ⑤
9. The learning process was facilitated by the methodology and tools used in this course.	① ② ③ ④ ⑤
10. The instructor displayed good communication skills.	① ② ③ ④ ⑤
11. The instructor explained well.	① ② ③ ④ ⑤

12.	The instructor gave me sufficient time to understand the work I had to learn.	① ② ③ ④ ⑤
13.	The instructor was empathetic and seemed to understand difficulties I might be having with my work.	① ② ③ ④ ⑤
14.	The instructor provided helpful feedback on how I was doing.	① ② ③ ④ ⑤
15.	The course stressed techniques that stimulated my interest in the content being covered and the instructor welcomed questions on these.	① ② ③ ④ ⑤
16.	The instructor aroused my interest to learn other topics in statistics.	① ② ③ ④ ⑤
17.	The instructor has confidence in his knowledge of statistics.	① ② ③ ④ ⑤
18.	The instructor deserved recommendation basing from my knowledge gained in this course.	① ② ③ ④ ⑤

Open-ended Question:

(a) Give important aspects of this course.

____

____

(b) Provide constructive and actionable suggestions for course improvement.

____

____

APPENDIX J:

PRE-INSTRUCTION KNOWLEDGE TEST (PRE-TEST)

Student I.D.: __________

INSTRUCTIONS: Circle the letter next to the *BEST* answer to each question.

1. When arranging data into classes it is suggested that there be
   a. fewer than 5 classes
   b. between 5 and 20 classes
   c. more than 20 classes
   d. between 10 and 40 classes

2. The values of the variance and standard deviation are
   a. always negative
   b. always positive
   c. never zero
   d. always zero

3. Which of the following is the mean of the squared deviations of x values from the mean?
   a. mean
   b. standard deviation
   c. population variance
   d. sample variance

4. A summary measure calculated for the sample data is called
   a. a population parameter
   b. a population statistic
   c. a sample parameter
   d. a sample statistic

5. Which of the following measures are influenced by extreme values?
   a. mean
   b. median
   c. mode
   d. range

6. A study has been made of the number of hours a street light will operate before it burns out. If the standard deviation of this distribution was computed, the standard deviation would be measured in
   a. hours
   b. hours squared
   c. hours cubed
   d. there are no units attached to the standard deviation

7. The probability of an event is always
   a. greater than zero
   b. in the range zero to 1.0
   c. less than 1.0
   d. none of the above

8. Two equally likely events
   a. have the same probability of occurrence
   b. cannot occur together
   c. have no effect on the occurrence of each other
   d. none of the above

9. Two events are mutually exclusive if
   a. they do not overlap on a Venn diagram
   b. one event occurs, then the other cannot
   c. the probability of one does not affect the probability of the other
   d. both (a) and (b) are correct

10. Two independent events

a. have the same probability

b. cannot occur together

c. can occur together

d. have no effect on the occurrence of each other

11. The sum of the probabilities of all final outcomes of an experiment is always

a. 100

b. 10

c. 1.0

d. zero

12. The joint probability of two mutually exclusive events is always

a. 1.0

b. between 0 and 1

c. zero

d. none of the above

13. Two independent events are

a. always mutually exclusive

b. never mutually exclusive

c. always complementary events

d. none of the above

14. To apply the rule of addition, the events must be

a. independent

b. mutually exclusive

c. equally likely

d. not equally likely

15. For the probability distribution of a discrete random variable, the probability of any single value of x is always

a. in the range zero to 1

b. 1.0

c. less than 1.0

d. greater than 1.0

16. The parameters of the binomial probability distribution are

a. n, p, and q

b. n and p

c. n and q

d. n, p, and x

17. The parameters of a Normal distribution are

a. μ, σ and z

b. μ, σ and x

c. μ and σ

d. μ, σ, x and z

18. The Normal distribution is applied to

a. a continuous random variable

b. a discrete random variable

c. any random variable

d. none of the above

19. A z value is

a. the deviation from the mean divided by the standard deviation

b. the mean of a distribution

c. the standard deviation of a distribution

d. none of the above

20. The z value for μ for a Normal curve is always

a. negative

b. positive

c. zero

d. either positive of negative

21. A sampling distribution is the probability distribution of

a. a population parameter

b. a sample statistics

c. any random variable

d. none of the above

22. The mean of the sampling distribution of $\bar{x}$ is always equal to

a. μ

b. $\mu - 5$

c. σ

d. $\sigma/\sqrt{n}$

23. A one-tailed test

a. has one critical region

b. has one acceptance region

c. both (a) and (b)

d. neither (a) nor (b)

24. A test of hypothesis is always about

a. a population parameter

b. a sample statistic

c. a test statistic

d. none of the above

25. A two-tailed test is a test with

a. two critical regions

b. two acceptance regions

c. two test statistics

d. none of the above

26. The computed value of a test statistic is the value

a. calculated from a sample statistic

b. determined from a table (e.g. The normal distribution table)

c. both (a) and (b)

d. neither (a) nor (b)

27. A critical value is the value

a. calculated from the sample data

b. determined from a table (e.g. The normal distribution table)

c. both (a) and (b)

d. neither (a) nor (b)

28. If the probability of a Type I error is α, then the probability of a Type II error is

a. also α

b. $1-\alpha$

c. 0

d. unknown

29. In a test of significance,

a. it is possible to prove the alternative hypothesis

b. it is possible to find evidence to support the alternative

c. it is not possible to find evidence to support the alternative

d. none of the above

30. If the null hypothesis is rejected, then

a. only a Type I error is possible

b. only a Type II error is possible

c. both Type I and Type II errors are possible

d. neither a Type I nor a Type II error is possible

31. The critical value for a one-tailed z-test with a 0.05 level of significance is

a. -1.96

b. -1.65

c. 1.65

d. 1.96

32. Which of the following is not required to apply the t distribution to make a test of hypothesis about μ?

a. $n < 30$

b. the population is approximately Normally distributed

c. σ is unknown

d. β is known

33. The t distribution approaches which distribution as the sample size increases?

a. binomial

b. normal

c. normal approximation to the binomial

d. all of the above

34. Which of the following statements about the t distribution are correct?

a. it has a mean of 0

b. it is symmetrical

c. it is based on the number of degrees of freedom

d. all of the above

35. The value of the correlation coefficient is always in the range

a. 0 to 1

b. -1 to 1

c. -1 to 0

d. none of the above

36. If there is a significant association between two variables, then the variables are

a. confounded

b. correlated

c. biased

d. independent

37. Pearson's r was computed to be -0.55. Which of the following values of r represents a stronger relationship than -0.55?

a. 0

b. +0.50

c. -0.70

d. 20.9

38. What kind of relationship exists if Y decreases as X increases?

a. inverse

b. direct

c. significant

d. no relationship

39. A simple regression is a regression model that contains

a. only one independent variable

b. only one dependent variable

c. more than one independent variable

d. both (a) and (b)

40. In the equation $\hat{y} = ax + b$, the letter a stands for

a. the coefficient of correlation

b. the coefficient of determination

c. the slope of the regression line

d. the y-intercept of the regression line

41. A variable about which predictions or estimates are to be made is called

a. the dependent variable

b. the discrete variable

c. the independent variable

d. the correlation variable

42. A (simple) linear regression means that the relationship between the independent variable and the dependent variable is that of

a. a straight line

b. a parabola

c. a hyperbola

d. a cycloid

43. A regression equation is used to

a. predict the value of the independent variable based on the dependent variable

b. predict the value of the dependent variable based on the independent variable

c. measure the association between two variables

d. explain the percent of variation in the dependent variable that is explained by the variation in the independent variable

44. The least squares regression line minimizes the sum of

a. errors

b. squared errors

c. predictions

d. none of the above

45. The one-way ANOVA test analyses only one

a. variable

b. population

c. sample

d. none of the above

46. The one-way ANOVA test is always

a. right-tailed

b. left-tailed

c. two-tailed

d. neither one- nor two-tailed

47. The ANOVA test can be applied to compare

a. two or more population means

b. more than two population means

c. more than three population means

d. more than four population means

48. If the population means for each of the treatment groups were identical, the value of the F statistic would be

a. equal to 1.00

b. 0

c. infinite

d. a number between 0 and 1.00

49. The F distribution

a. cannot be negative

b. is positively skewed for small samples

c. is determined by two parameters

d. all of the above are correct

50. In a particular ANOVA test, the calculated value of F is between 0 and the value of the F table. The correct conclusion is

a. accept H_0 and conclude that the treatment means being tested are not significantly different

b. accept H_0 and conclude that the treatment means being tested differ significantly

c. reject H_0, accept H_1, and conclude that the treatment means are not significantly different

d. reject H_0, accept H_1, and conclude that the treatment means are significantly different

APPENDIX K:

POST-INSTRUCTION KNOWLEDGE TEST (POST-TEST)

Student I.D.: __________

INSTRUCTIONS: Circle the letter next to the *BEST* answer to each question.

1. For the probability distribution of a discrete random variable, the sum of the probabilities of all values of x is always
   a. greater than zero
   b. 1.0
   c. less than 1.0
   d. greater than 1.0

2. The standard deviation of the sampling distribution of $\bar{x}$ is always equal to
   a. μ
   b. $\mu - 5$
   c. σ
   d. $\sigma/\sqrt{n}$

3. In a test of significance,
   a. it is possible to prove the alternative hypothesis
   b. it is possible to find evidence to support the alternative
   c. it is not possible to find evidence to support the alternative
   d. none of the above

4. Which of the following is the mean of the squared deviations of x values from the mean?
   a. mean
   b. standard deviation
   c. population variance
   d. sample variance

5. Two independent events

   a. have the same probability
   b. cannot occur together
   c. can occur together
   d. have no effect on the occurrence of each other

6. A simple regression is a regression model that contains

   a. only one independent variable
   b. only one dependent variable
   c. more than one independent variable
   d. both (a) and (b)

7. A summary measure calculated for the sample data is called

   a. a population parameter
   b. a population statistic
   c. a sample parameter
   d. a sample statistic

8. The Normal distribution is applied to

   a. a continuous random variable
   b. a discrete random variable
   c. any random variable
   d. none of the above

9. The one-way ANOVA test is always

   a. right-tailed
   b. left-tailed
   c. two-tailed
   d. neither one- nor two-tailed

10. Two independent events are

   a. always mutually exclusive
   b. never mutually exclusive
   c. always complementary events
   d. none of the above

11. The least squares regression line minimizes the sum of

   a. errors
   b. squared errors
   c. predictions
   d. none of the above

12. A z value is

   a. the deviation from the mean divided by the standard deviation
   b. the mean of a distribution
   c. the standard deviation of a distribution
   d. none of the above

13. The probability of an event is always

   a. greater than zero
   b. in the range zero to 1.0
   c. less than 1.0
   d. none of the above

14. Two equally likely events

   a. have the same probability of occurrence
   b. cannot occur together
   c. have no effect on the occurrence of each other
   d. none of the above

15. In a particular ANOVA test, the calculated value of F is between 0 and the value of the F table. The correct conclusion is

    a. accept H_0 and conclude that the treatment means being tested are not significantly different
    b. accept H_0 and conclude that the treatment means being tested differ significantly
    c. reject H_0, accept H_1, and conclude that the treatment means are not significantly different
    d. reject H_0, accept H_1, and conclude that the treatment means are significantly different

16. Which of the following measures are influenced by extreme values?

    a. mean
    b. median
    c. mode
    d. range

17. The standard normal z value

    a. may be used to compare the relative position of an observation on two normal distributions
    b. is calculated by the formula $(X-\mu)/\sigma$
    c. is used to calculate the probabilities associated with any normal distribution
    d. all of the above are correct

18. The sum of the probabilities of all final outcomes of an experiment is always

    a. 100
    b. 10
    c. 1.0
    d. zero

19. Which of the following is not required to apply the t distribution to make a test of hypothesis about μ?

   a. $n < 30$
   b. the population is approximately Normally distributed
   c. σ is unknown
   d. β is known

20. A 95% confidence interval for μ can be interpreted to mean that if we take 100 samples of the same size and construct 100 such confidence intervals for μ, then

   a. 95 of them will not include μ
   b. 95 will include μ
   c. 95 will include $\overline{x}$
   d. none of the above

21. Which of the following is not a condition of the binomial experiment?

   a. There are n identical trials
   b. Each trial has only two possible outcomes
   c. Equality of the population variances (homoscedasticity)
   d. The trials are independent

22. The parameters of a Normal distribution are

   a. μ, σ and z
   b. μ, σ and x
   c. μ and σ
   d. μ, σ, x and z

23. The ANOVA test can be applied to compare

   a. two or more population means
   b. more than two population means
   c. more than three population means
   d. more than four population means

24. Two events are mutually exclusive if

a. they do not overlap on a Venn diagram

b. one event occurs, then the other cannot

c. the probability of one does not affect the probability of the other

d. both (a) and (b) are correct

25. A test of hypothesis is always about

a. a population parameter

b. a sample statistic

c. a test statistic

d. none of the above

26. If the level of confidence is increased from 95% to 99% but the allowable error and the standard deviation remain the same, the required sample size will

a. increase

b. decrease

c. stay the same

d. all of the above

27. The t distribution approaches which distribution as the sample size increases?

a. binomial

b. normal

c. normal approximation to the binomial

d. all of the above

28. The z value for μ for a Normal curve is always

a. negative

b. positive

c. zero

d. either positive of negative

29. A two-tailed test is a test with
   a. two critical regions
   b. two acceptance regions
   c. two test statistics
   d. none of the above

30. The joint probability of two mutually exclusive events is always
   a. 1.0
   b. between 0 and 1
   c. zero
   d. none of the above

31. If the population means for each of the treatment groups were identical, the value of the *F* statistic would be
   a. equal to 1.00
   b. 0
   c. infinite
   d. a number between 0 and 1.00

32. The values of the variance and standard deviation are
   a. always negative
   b. always positive
   c. never zero
   d. always zero

33. A one-tailed test
   a. has one critical region
   b. has one acceptance region
   c. both (a) and (b)
   d. neither (a) nor (b)

34. If the null hypothesis is rejected, then

a. only a Type I error is possible

b. only a Type II error is possible

c. both Type I and Type II errors are possible

d. neither a Type I nor a Type II error is possible

35. The computed value of a test statistic is the value

a. calculated from a sample statistic

b. determined from a table (e.g. The normal distribution table)

c. both (a) and (b)

d. neither (a) nor (b)

36. When samples are taken from a nonnormally distributed population, the sampling distribution of the sample mean has a normal distribution

a. when $n \geq 10$

b. when $n \geq 30$

c. when $n/N \leq 0.05$

d. always

37. A (simple) linear regression means that the relationship between the independent variable and the dependent variable is that of

a. a straight line

b. a parabola

c. a hyperbola

d. a cycloid

38. A critical value is the value

a. calculated from the sample data

b. determined from a table (e.g. The normal distribution table)

c. both (a) and (b)

d. neither (a) nor (b)

39. To apply the rule of addition, the events must be

a. independent

b. mutually exclusive

c. equally likely

d. not equally likely

40. Which of the following statements about the *t* distribution are correct?

a. it has a mean of 0

b. it is symmetrical

c. it is based on the number of degrees of freedom

d. all of the above

41. A regression equation is used to

a. predict the value of the independent variable based on the dependent variable

b. predict the value of the dependent variable based on the independent variable

c. measure the association between two variables

d. explain the percent of variation in the dependent variable that is explained by the variation in the independent variable

42. If the probability of a Type I error is α, then the probability of a Type II error is

a. also α

b. $1-\alpha$

c. 0

d. unknown

43. The critical value for a one-tailed z-test with a 0.05 level of significance is

a. -1.96

b. -1.65

c. 1.65

d. 1.96

44. If there is a significant association between two variables, then the variables are

a. confounded

b. correlated

c. biased

d. independent

45. The F distribution

a. cannot be negative

b. is positively skewed for small samples

c. is determined by two parameters

d. all of the above are correct

46. Pearson's r was computed to be -0.55. Which of the following values of r represents a stronger relationship than -0.55?

a. 0

b. +0.50

c. −0.70

d. 20.9

47. What kind of relationship exists if Y decreases as X increases?

a. inverse

b. direct

c. significant

d. no relationship

48. In the equation $\hat{y} = ax + b$, the letter a stands for

a. the coefficient of correlation

b. the coefficient of determination

c. the slope of the regression line

d. the y-intercept of the regression line

49. When arranging data into classes it is suggested that there be

a. fewer than 5 classes

b. between 5 and 20 classes

c. more than 20 classes

d. between 10 and 40 classes

50. A variable about which predictions or estimates are to be made is called

a. the dependent variable

b. the discrete variable

c. the independent variable

d. the correlation variable